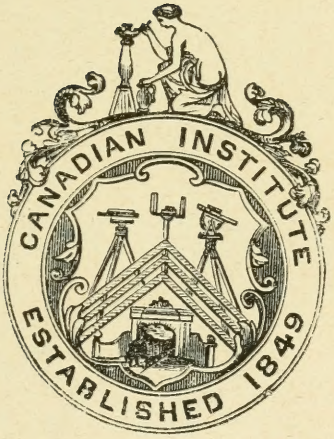
TRANSACTIONS

OF

The Canadian Institute

VOLUME VIII



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TRANSACTIONS

OF

THE CANADIAN INSTITUTE.

THE FLUCTUATIONS OF LAKE ONTARIO.

(SEMI-CENTENARY.)

By Kivas Tully, C.E., I.S.O.

(Read 9th January, 1904.)

The semi-centenary of the Canadian Institute was celebrated on December 9th, 1899, His Excellency Lord Minto, Governor-General of the Dominion of Canada, and other notabilities being present, the records of which were published in the semi-centennial volume of the Institute. It is my purpose now to lay before the Institute the particulars connected with the fluctuation of the waters of Lake Ontario, for a period of fifty years. On March 22nd, 1879, I read a paper on this subject before the Institute. The fluctuations were from 1854 to 1878 inclusive, a period of twenty-five years. On February 10th, 1894, the observations were continued to the end of 1893, an additional period of fifteen years, making a total of forty years, also read before the Institute. In continuing the subject to the end of 1903, for the additional ten years, a condensed recapitulation is advisable. The great lakes of North America are the reservoirs of the water sheds which lie between 76° and 92° west longitude, and 42° and 50° north latitude, running in a diagonal or north-westerly direction. Since 1878 the survey of the great lakes

has been completed by the United States Army Engineers, the results of the survey being as follows:—

Lakes.	Area of Water Surface—Square Miles.	Area of Water Shed—Square Miles.	Aggregate Area of Basin—Square Miles.
Lake Superior	31,200	51,600	82,800
Saint Mary's River	150	800	950
Lake Michigan	22,450	37,700	60,150
Lake Huron and Georgian Bay	23,800	31,700	55,500
Saint Clair River	25	3,800	3,825
Lake Saint Clair	410	3,400	3,810
Detroit River	25	1,200	1,225
Lake Erie	9,960	22,700	32,660
Niagara River	15	300	315
Lake Ontario	7,240	21,600	28,840
Totals	95,275	174,800	270,075

The levels of the mean surfaces of the lakes above the mean sea level at Governor's Island, New York, are: Lake Ontario, $246\frac{6}{10}$ feet; Lake Erie, $572\frac{9}{10}$; Lakes Huron and Michigan, $581\frac{3}{10}$ feet; and Lake Superior, $601\frac{8}{10}$ feet. The difference of $20\frac{1}{2}$ feet between Lakes Superior and Huron occurs in the rapids of Saint Mary's River, the $8\frac{4}{10}$ between Lakes Huron and Erie, mainly in the Detroit River. The difference of 326 feet between Lakes Erie and Ontario occurs in the vicinity of Niagara Falls, and is principally grouped as follows: 100 feet in the 5 miles of rapids between Lewiston and the Lower Suspension Bridge; 10 feet in the rapids between the bridge and the falls; 160 feet at the falls; 50 feet in the rapids immediately above the falls, and 6 feet in the Upper Niagara River.

The mean depth of Lake Superior is about 475 feet, the deepest point marks a depth of 1,008 feet, or 406 feet below the level of the sea. Lake Huron has a mean depth of about 250 feet, and a maximum depth of 750 feet. Lake Michigan has a mean depth of 325 feet, and a maximum depth of 870 feet. Lake Erie is comparatively shallow, having an average depth of less than 70 feet, and a maximum depth of 210 feet. Lake Ontario has a mean depth of about 300 feet, and a maximum of 738 feet, or nearly 500 feet below sea level. The channels of the rivers connecting the lakes seldom exceed 50 feet. According to the United States lake surveys, the mean actual rain and melted snowfalls of the several lake basins are: Lake Superior, 29 inches; Lake Huron, 30 inches; Lake Michigan, 32 inches; Lakes Erie and Ontario, 34 inches. This is about equal to 31 inches on the entire lake basin. The following represent the average discharges of the lakes: Lake Superior, at Saint

Mary's River, 86,000 cubic feet per second; Lakes Michigan and Huron, at Saint Clair River, 225,000 cubic feet per second; Lake Erie, at Niagara, 265,000 cubic feet per second; Lake Ontario, at Saint Lawrence River, 300,000 cubic feet per second. It is well understood that the principal factors on which the stage of water in the great lakes depends, are the rain and snowfalls, the evaporation, and winter temperature; the rain and snowfalls furnish the supply, the evaporation withdraws a part before it reaches the mouths of the streams and forms the surfaces of the lakes; a severe and continued cold winter preventing the melting of the snow will raise the summer stage at the expense of the winter stage.

The following is a detailed statement of the rain and snowfalls from 1854 to 1903, and the highest and lowest water on Lake Ontario:—

	Rain and Snowfall —Inches.	Highest Water.	Lowest Water.	Remarks.
1854	32.715	June 21st..26½	Dec. 29th..6	Great fall.
1855	41.550	Aug. 7th..29¾	April 2nd..1	Water rising.
1856	27.055	June 11th..32½	Dec. 15th..4½	Water falling.
1857	40.795	July 27th..43½	Jan. 20th..1½	Great rise.
1858	32.591	July 13th..44	Nov. 30th..17½	Water Steady.
1859	39.764	May 31st 43	Nov. 14th..12½	Great fall.
1860	29.994	July 8th..24½	Nov. 24th..11	Rise and fall equal.
1861	34.475	June 5th..39	Jan. 30th..9	Great rise.
1862	34.009	May 21st..43½	Dec. 19th 8	Great fall.
1863	32.775	May 16th..34½	Dec. 15th..8	Great fall.
1864	36.946	June 5th..35½	Feb. 15th..4	Great rise.
1865	32.929	May 19th..30	Dec. 27th..zero	Great fall.
1866	39.429	June 18th..20	Feb. 15th – 7	Water even.
1867	30.091	June 17th..38	Dec. 26th – 5	Great fall.
1868	34.278	July 1st..17	Feb. 6th – 12	Low water.
1869	39.642	July 28th..27	Feb. 5th – 2	Water rising.
1870	46.188	*May 6th*..47	Dec. 29th..12	Highest water.
1871	32.731	May 4th..26	Dec. 29th – 6½	Great fall.
1872	25.338	June 22nd..3¼	*March 19th* – 16½	Lowest water.
1873	31.612	May 26th..23	Jan. 9th – 15	Great rise.
1874	*24.344*	June 11th..29	Dec. 30th – 5	Fall at end of year.
1875	29.730	June 24th. 12	Feb. 17th – 15	Very steady.
1876	32.405	July 5th 41	Jan. 10th – 2	Great rise.
1877	25.615	April 28th..18½	Nov. 18th – 1½	Low water.
1878	*48.490*	Dec. 14th..25	Jan. 5th – 1	High water.
1879	29.365	Jan. 1st..22	Oct. 30th – 6½	Gradual fall.
1880	35.322	June 4th..19	Dec. 30th – 7	Rise and fall equal.
1881	26.858	July 8th..15	Dec. 7th – 7	Rise and fall equal.
1882	*24.837*	June 30th..29½	Jan. 3rd – 3	Rise and fall equal.
1883	34.134	July 16th..36	Jan. 21st – 2	Rise and fall equal.
1884	28.552	May 22nd..40	Nov. 24th..9	High water.
1885	32.911	Aug. 3rd..34	March 10th..4	High water.

	Rain and Snowfall —Inches.	Highest Water.	Lowest Water.	Remarks.
1886	35.076	*May 10th*..46	Nov. 15th..14½	High water.
1887	25.759	May 30th..39	Dec. 29th..3	Low water.
1888	26.279	June 28th..17½	Dec. 21st..zero	Low water.
1889	31.325	July 3rd..22	Nov. 4th – 1	Low water.
1890	37.370	June 1st..37	Jan. 8th..8	High water.
1891	31.515	May 2nd..29	Dec. 16th – 13½	Very low.
1892	29.505	July 24th..14½	*March 7th* – 13½	Very low.
1893	*39.715*	June 1st..27	Feb. 7th – 9	Very low.
1894	29.565	*June 3rd*..19	Dec. 27th – 10	Lowest yet.
1895	28.011	*May 28th* – 2⅓	*Nov. 20th* – 25	Lowest.
1896	29.100	May 28th..4	Jan. 20th – 20	Rise and fall equal.
1897	32.477	July 27th..9½	Jan. 28th – 23	Average, 5 below.
1898	30.950	May 19th..15	Dec. 23rd – 9½	Average, 3 above.
1899	28.975	June 4th..15	Dec. 6th – 12	Average, 2 above.
1900	29.590	May 16th..21	Nov. 21st – 16	Average, 1½ above.
1901	32.270	June 25th..12	Dec. 10th – 15	Average, ¾ below.
1902	31.025	July 30th..14½	Jan. 3rd – 11	Average, 2⅔ above.
1903	30.631	May 2nd..20	Dec. 27th – 8½	Average, 9 above.

N.B.—Where the sign (–) minus is used it indicates the level below zero. Zero was established in 1854, being 9 feet above the rock at the Queen's Wharf.

In the paper which I read at the Institute in 1879, it was stated that the average rain and melted snowfalls for twenty-five years were 34.172 inches, the highest being 48.490 in 1878, and the lowest 24.344 inches in 1874. The average rain and snowfalls for fifteen years, from 1878 to 1893, were 31.217 inches, the highest being 39.715 inches in 1893, and the lowest 24.837 inches in 1882. The extreme fluctuations of Lake Ontario between the years 1854 and 1878, inclusive, were, in 1870, when the highest water was reached on May 6th, 47 inches, and two years afterwards the lowest water occurred on March 19th, 1872—16¼ inches, an extreme of 63¼ inches. The extreme fluctuations between the years 1878 and 1893, were, in 1886, when the highest water was reached on May 16th, 46 inches, and in 1892, not quite six years afterwards, the lowest water occurred on March 7th—13½ inches, an extreme of 59½ inches, nearly 4 inches less than the extreme fluctuations for the previous twenty-five years. The mean average for the twenty-five years was 18.20 inches, and for the fifteen years between 1878 and 1893, was 15.17 inches. The diminution of nearly 3 inches in the rain and snowfalls, and more than 3 inches in the fluctuations of the above periods, induced me to examine the average rain and snowfalls, as recorded by the Meteorological Observatory, Toronto, and I found that the above diminutions of the rain and snowfalls, and the fluctuations of Lake Ontario, were nearly substantiated as follows :—

In 1858 the average of seventeen years was 36.940 inches.
In 1868 the average of twenty-seven years was 36.273 inches.
In 1878 the average of thirty-seven years was 35.464 inches.
In 1888 the average of forty-seven years was 34.632 inches.
In 1893 the average of fifty years was 34.338 inches.

Showing a gradual diminution from the highest in 1858 to the lowest in 1893 of 2.602 inches, for fifty years. I then stated that "the cause of the diminution was not far to seek, the reckless destruction of the forests in Ontario, also Michigan and Wisconsin, in the United States, by lumbering, and consequent fires, in the area of the watershed of the great lakes, without a partial or corresponding substitution of trees by planting, is a sufficient explanation of the result, apart from other probable causes." This statement has been more than corroborated by the observations of the last ten years, namely, from 1893 to 1903, as follows: The diminution of the rain and snowfalls has been 1.583 inches, and the fluctuations of Lake Ontario, for the same period, has been 10.34 inches. This decrease may be partly explained that the decade from 1893 to 1903 has been a period of very low water (see record). With respect to the diminution of the rain and snowfalls from 1854 to 1903, the statement has also been corroborated by a return recently made by the Harbour Master, Mr. Postlethwaite, and published in the Toronto "Telegram." In this return the average from 1854 to 1863 was 34.668 inches; from 1863 to 1873, 34.919 inches; from 1873 to 1883, 31.311 inches; from 1883 to 1893, 31.801 inches; and from 1893 to 1902, 30.218 inches, a diminution of 4.450 inches for the last forty-nine years, from 1854 to 1902. (*N.B.*—The rain and snowfalls for 1903 are 30.631 inches, but not included in the above return, which would be slightly diminished.)

The following extracts from the "Report on Forestry" for 1896 are so pertinent to the intimate connection between the diminution of the rain and snowfalls and deforestation that I cannot avoid quoting them at length (see page 8): "The question of the preservation of the forests has simply been forced upon public attention by the sheer necessities of the case. With the steady expansion of the settled and cultivated area, and the growth of population, the evils resulting from deforestation have become greatly intensified. The climatic changes foreshadowed by the earlier students of the subject, as the inevitable result of the reckless destruction of the woods, have been developed in a large measure, and the lessons of practical experience have brought conviction to those who would have been impervious to the universal teachings of history. Almost every spring now brings calamitous floods and freshets down the

water-courses, along which the streams, fed by the melting snows and the spring rains, formerly flowed gradually away. Periods of protracted drought during midsummer are much more severe in their effects. The sweep of the winter winds over large cleared areas of country, in many localities, renders difficult and precarious the growth of some crops once profitably cultivated. The largely-increased demand for timber for manufacturing purposes is met by a rapidly diminishing supply. The prospect of the further deterioration of the soil and climate, and the exhaustion of the vast and supposedly illimitable timber resources of the Continent, has naturally induced a close study of the causes of conditions so unfavourable to future prosperity and industrial development."

Under the head of "Forests and Rainfall," at page 14 of the report, Mr. Southworth states: "It may here be remarked in passing that though this author takes very decided ground as to the effect of the forest in increasing the actual volume of the rainfall, the question is one upon which some difference of opinion still exists among meteorologists. As all rainfall is dependent upon evaporation, and no drop of water can possibly fall anywhere upon the earth's surface that has not first been drawn from it, it is urged that the aggregate evaporation, which is mainly from the ocean, the great lakes, and other bodies of water, cannot possibly be affected by the transpiration from the leaves of trees to such an extent as to appreciably increase the rainfall. On the other hand, the evaporation of moisture due to the presence of forests is very great. Aside from the longer retention of the water in a forest floor, allowing it to evaporate gradually, instead of running at once to the streams and to the sea, the amount of moisture transpired through the leaves of a large and healthy tree is much larger than is generally supposed.

"Areas entirely destitute of trees are more subject to drought than districts in which there is a proper proportion of wooded land. The summer of 1895 was an exceptionally dry one in many parts of Ontario, and it is worthy of note, that the section of the province which suffered most severely from the want of rain, was the region that, according to the assessment returns of the Ontario Bureau of Industries, has been the most completely denuded of its timber."

The annual reports on forestry since 1896 indicate that some progress has been made in this most important and urgent matter, affecting, as it does, the prosperity and welfare of the province. By the report of the Director of Forestry, Mr. Southworth, for 1900 and 1901, it will be observed, that in addition to the Algonquin Park reserve of 1,109,383

acres, set apart in 1893, timber under license not included, there have been 80,000 acres set apart as an Eastern reserve, the Sibley reserve of 45,000 acres, and the Temagami reserve of 1,408,000 acres. In 1898 the Ontario Legislature adopted the "Forests Reserves Act," empowering the Lieut.-Governor-in-Council to set apart tracts of such lands as forest reserves as from time to time may be deemed advisable. The passing of the above Acts, also by the appointment of a Commission in 1897, and setting apart forest reserves, indicate the care of the Ontario Government to rectify as far as possible the effects of deforestation. The assessment returns of the forestry report contain valuable statistics as to the total acreage and woodland of the Ontario townships, and the Director of Forestry remarks at page 45 of the report: "On the basis of these returns, as well as from other sources of information, it is evident that in much of the older settled portion of the province, the proper proportion of wooded to cleared land no longer exists, and evidence is not wanting that we have begun seriously to feel the effects of over-clearance. Farmers are now noting the disadvantage of having no forests to stop the sweep of the winds, owing to which the snow is blown off the fields in winter, and the moisture quickly evaporated in the summer, while the melted snow and rain at all seasons runs rapidly off the surface instead of being gradually absorbed into the soil. While many of the farmers already realize the damage to agriculture caused by over-clearance, few have made any attempt to improve the condition of affairs by replanting or by adequately preserving their existing wood lots. That something should be done to correct the process of forest removal in Southern Ontario is obvious, and just what steps to pursue to accomplish this end is not so apparent." The recent sale of timber limits in New Ontario on December 9th last, shows that the evil effects of deforestation will be continued without any reservation as to the smaller growth of timber, and the Bureau of Forestry will have to devise means for rectifying the omission by replanting. The chief points of the sale of timber limits in the districts of Algoma and Rainy River were as follows :—

Total amount, $3,677,337.50, for 826½ square miles, an average price of $4,450 per square mile. If a small percentage of this large amount was set apart for reforestation, it would assist to mitigate the evil effects of the wholesale destruction of the forests. The disposal of the pulp wood limits is also a cause of deforestation, particularly as the smaller timber is used for pulp wood, and, consequently, there would be no reservation. In connection with this subject I cannot avoid quoting some extracts from a work on practical forestry, by John Gifford, 1902, as-

sistant professor of forestry, New York State College of Forestry, Cornell University: "The President of the United States can withdraw from sale or entry, and set apart by proclamation, parts of the public domain. These are called forest reservations. Presidents have used this power freely, so that the area reserved, including national parks, approximate in round numbers to 50,000,000 acres. These reservations are set aside for three important purposes—first, the preservation of the timber; second, the preservation of natural curiosities and extraordinary scenery; and, third, for the *conservation of the water supply.*" (Comments, Introductory Notes, chap. i.).

"The forest and water problems are perhaps the most vital internal questions of the United States." (President Roosevelt, part iii., "The Industrial Importance of Forests.")

"How foolishly men destroy the forest cover without any regard to consequences, for thereby they rob themselves of wood and water!" (Humboldt).

My remarks on this subject are more extended than was at first contemplated, but as my conclusions as to the effects of deforestation on the rain and snowfalls were questioned when I read my second paper in 1894, I consider I am justified in quoting some authorities in support of my statement. Mr. Stupart, the Director of the Meteorological Observatory, Toronto, has given some attention to this subject, having read a paper on February 22nd, 1896, on the rain and snowfalls at stations in all the great lakes, whilst my observations were limited to the records of the Observatory at Toronto. Many of the stations referred to by Mr. Stupart were established since 1874, when the meteorological service was inaugurated, though observations have been made since 1840. At the conclusion of his paper Mr. Stupart remarks that, "Meteorologists have so far been unable to prove that terms of excessive rainfall, or the contrary, are periodical." Also, "We can understand that we are dealing with a very complicated subject, and that observations during a long period of years will be necessary to unravel the mystery." On February 28th, 1896, Mr. Stupart wrote: "I shall continue the investigation, and hope to get at the truth one of these days." We have the correct observations made at the Meteorological Observatory, Toronto, from 1840 to 1902, and from these observations there can be only one conclusion, that there has been a diminution of rain and snowfalls of 3.147 inches—the difference between the average for sixty-two years and fifty years, 1.303 inches, may be explained that the first period of seventeen years was that of the highest average rain and snowfalls recorded, *viz.*, 36.940

inches. The harbour records from 1854 to 1903 show a diminution of the water level of Lake Ontario of 13.61 inches. This great diminution in fifty years demands close scrutiny and enquiry, as the diminution of the rain and snowfalls does not explain the discrepancy. During the last period of ten years the Sanitary Canal at Chicago has been completed, and the outlet from Lake Ontario, at the Galops rapids, has been deepened, which may account for the extraordinary diminution. I have no accurate data with respect to these constructions, but when it is considered that the drainage of Chicago has been diverted from Lake Michigan to the River Mississippi, the water levels of Lakes Michigan, Huron, Erie and Ontario must be considerably affected. An expert was appointed by the Dominion Government to examine and report on the discharge of the Sanitary Canal at Chicago, but I am not aware that any examination or report was made. The Dominion Government is now constructing a dam between the Galops and Adam's Islands, at the head of the Galops rapids. This dam is only constructed in order to increase the depth of water in the rapids, but not intended to raise the water level of Lake Ontario. The decrease in the water levels of the lakes can be rectified by engineering skill—in fact a dam has already been recommended to be constructed across the Niagara River, near Buffalo, to regulate the water level of Lake Erie, and the Detroit River, but the diminution of the rain and snowfalls cannot be checked except by replanting and reforestation. As the period of low water on Lake Ontario occurs generally during the winter months, the shipping interests are not much affected, but dredging is constantly required in the harbours round Lake Ontario.

The record of extraordinary fluctuations is limited to one instance, which was detected by Denison's automatic gauge, placed in the storm signal house at the Queen's Wharf, by the Dominion Government in 1898, the particulars of which I notified Mr. Stupart on November 29th, 1900, requesting to be informed if there was any unusual disturbance of the barometer at the Observatory at that time. "On Monday, the 26th inst., there was an extraordinary fluctuation of the lake level from 5.45 to 6 a.m., wind strong from the north-west. The reading at 5.45 a.m. was 1.60 inches above Dominion zero, in ten minutes the reading was a little below 1.00, and in fifteen minutes it went up to 2.25 inches, at 6 a.m. The level gradually subsided to the normal reading for the day." On November 30th Mr. Stupart replied: "I enclose herewith a print of our barogram, showing a marked and rapid change of barometer at about the time you say there was an extraordinary fluctuation in lake level. The change of reading between 5 o'clock, and the lowest, 5.30,

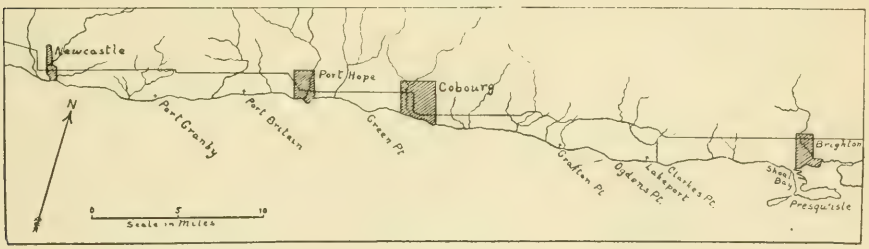
was .082, and the change in ten minutes was .06. I also enclose a tracing of the air barometer curve, which shows the change very nicely." On December 6th, 1900, I enclosed a tracing of the record on Denison's automatic gauge, which corresponds with the tracing sent by Mr. Stupart. There was no apparent cause for the extraordinary fluctuation, no notice in the newspapers, and the disturbance remains unexplained. I also reminded Mr. Stupart of an extraordinary fluctuation on April 24th, 1878, the difference in level being $3\frac{1}{2}$ feet. The particulars were given in the paper which I read to the Institute in 1894. Mr. Stupart replied that "the record in April, 1878, was .08 in four minutes. The cause of this disturbance, also, has never been explained." With reference to the supposed tidal theory, General Comstock, of the United States Survey, remarked: "The known existence of a lake breeze at Milwaukee during the summer months at once suggested itself as a cause for this inequality, and on comparing the solar diurnal curve for April and November, when the lake breeze should be weak, and that for July and August, when the lake breeze should be strongest, with that of the whole season, it was found that for the former months the inequality entirely disappears, while for the latter it is considerably increased, thus justifying the supposition that the lake breeze is the cause of the inequality." On such evidence the so-called tidal theory may be dismissed. The supposed rise and fall of the water level of Lake Ontario, every seven years, may also be dismissed. An examination of the harbour profile of the water levels will be sufficient to dispose of any such theory, the rise and fall being quite irregular, not even corresponding with the rainfall. My task is now done, and I shall have to leave future observations to others, who, I trust, will do justice to the subject. The records of fluctuations will be continued, to which reference can be made in the Harbour Office at any time.

A FORTY-MILE SECTION OF PLEISTOCENE DEPOSITS NORTH OF LAKE ONTARIO.

By Alfred W. G. Wilson, McGill University, Montreal.

(Read 7th March, 1903.)

The north shore of Lake Ontario from Presqu'isle, near the village of Brighton, Northumberland County, to a little west of Lorne Park, west of the City of Toronto, a distance slightly over one hundred miles in all, is formed for the most part by the pleistocene deposits of Central Ontario. Along the shore through most of this distance there are numerous sections exposed where the waves have cut back into these deposits. The best known and most important of these sections is that at Scarboro, which was studied and described, first by Hinde, and later in more detail, by Coleman. In the present paper the writer presents a general description of the section exposed along the shore of the lake from Presqu'isle to the village of Newcastle, a distance of about forty miles, and a more detailed description of the last eight miles of the section, beginning a little west of Port Britain.



The rock exposures which occur along this part of the shore of Lake Ontario are always of Trenton limestone. At Presqu'isle rock forms a low escarpment. There is almost no covering of drift, though occasional boulders, usually of archæan rock, are found. In places there may be local deposits of sands, probably stratified, though there are no sections in which the internal structure can be obtained. West from Presqu'isle the next exposure of rock is found at Clarke's Point, about two miles east of Lakeport pier. At this point the soil cover overlying the rock is also very limited. Between the point and Shoal bay to the east there

are a number of places where the shore is formed by a barrier beach built by the waves, and the pleistocene deposits pass under the beach, no exposures being visible. Between these barrier beaches there are several places in which we find low cliffs, varying in height to a maximum of about twenty-five feet. The deposits in which the cliffs are cut consist chiefly of a compact and, in places, arenaceous till carrying numerous pebbles, cobbles, and some boulders. Overlying the till sheet, which is of irregular thickness, is a deposit of fine textured stratified sands. In places the low cliff is cut wholly in the sands, the till presumably being below water-level. In one locality the waves are now cutting into an old sand dune which must be of comparatively recent origin. About a mile and a-half west of Lakeport, at Ogden's Point, bed rock is not exposed on the shore, but it can be seen off shore beneath about six feet of water. The next exposure of rock occurs at Grafton point, about five miles west of Lakeport. At the point and for a short distance west of it the rock seems to be overlain by a deposit of stratified sand, though it is probable that there is a thin drift cover beneath. Immediately to the east of Grafton pier there is a small exposure of white clay till, apparently the remnant of a drumlin, now almost completely washed away by the waves. Commencing about a quarter of a mile east of the pier and extending for one and a-half miles is a cliff about thirty feet in height at its maximum, the upper part of which is formed by stratified sands. If the till occurs above lake level and beneath these sands it is obscured by the talus from the cliff. Beyond this cliff, eastward, the shore is bordered by a barrier beach the gravel of which is probably derived from a till deposit underlying the sands of this cliff. Still further east similar sands again form a low cliff, giving place, near Ogden's Point, to an arenaceous clay till, carrying numerous pebbles, cobbles, and some very large boulders and blocks. In places the till is overlain by thin deposits of sand. Just east of the point, and extending to Lakeport, the till forms a cliff about twenty feet in height. The surface rises rapidly inland to an elevation of about forty feet. Allowing for that which lies below water-level the total thickness must be about forty-five feet.

West from Grafton Point the upper surface of the sands which form the low cliff at the point, gradually becomes lower so that the land slopes gently down to lake-level. About three miles west of the point deposits of a compact argillaceous till again form a steep cliff with a maximum height of thirty feet, but gradually lowering both east and west. This till passes beneath the sands on either side of it. Continuing west along the shore the till gives place to sands. About three miles

and a-half east of Cobourg pier, immediately beneath these sands and overlying a deposit of boulder till, are found about eight feet of a distinctly stratified clay which presents a peculiar banding. The section is about one quarter of a mile in length. The banded appearance of the clay is due to the alternate deposition of fine and slightly coarser materials in beds varying from one-half to one inch in thickness. In this bedded clay are found numerous pebbles and small cobbles, some of the latter being distinctly striated. The most striking feature of the banding is that in places it is very much twisted and contorted, so much so that the contortions can be best likened to those found in contorted gneiss.

For the next five miles, to a little beyond the western boundary of the town of Cobourg, clay till occurs with bed rock outcropping from beneath it at frequent intervals. This till reaches its maximum thickness, about forty-five feet, a mile and a-half east of Cobourg pier. In the western part of the town the upper surface of the till near the lake is below water-level and is overlain by sand deposits. It again appears in a dome-shaped hill at Weller's Point a little further west. For the next mile, west from Weller's Point, the till is again overlaid by sands. The upper surface of these sands gradually descends to lake level, and from Green Point to within a mile of Port Hope the shore is formed by a barrier beach.

A mile off shore opposite Green Point lies Gull island, the most westerly exposure of Trenton limestone found along the shore of Lake Ontario.* Under the water there are numerous cobbles and a few boulders still lying on the bed rock. It is not improbable that at one time the island was formed by a drumlin, now long since removed by the waves.

The till sheet which forms the cliff east of Port Hope harbour extends along the shore for about a mile until it is interrupted by Smith's creek, which enters the lake at this place. A third of a mile west of the pier the shore section shows that it is overlaid by stratified sands. Half a mile further west these sands in turn are found to be capped by a second boulder till. A section at this place shows above lake level five feet of the lower till, ten feet of stratified sand, and six feet of the upper till. The thickness of the sands between the till sheets diminishes towards the west and at a mile and a-half west of the town the upper till rests upon the lower. A little over two miles west of Port Hope the

* Limestone is exposed in the bed of Smith's creek at Port Hope, a few chains north of the harbour.

sands again appear between the two sheets and the cliff section is about fifty feet in height. At three miles the upper till overlies the sands and the lower till lies below lake level. From this point for the next two miles the shore-line is marked by a barrier beach, the land behind is low and marshy. Then two low domes of the lower till form a low cliff for about one-quarter of a mile. A second barrier beach more than a mile in length intervenes between these low cliffs and the next series of deposits into which the waves have cut. From this place, about two and one-half miles west of Port Granby, to Newcastle pier there is a continuous section over eight miles in length, except for slight interruptions where two small creeks enter the lake. This section may be termed the Clarke section, because the greater part of it lies within the township of Clarke.

The structure of this section is much more complex than that of any of the preceeding sections and it has accordingly been studied in more detail. The shore line of Lake Ontario, represented on the accompanying map, was surveyed by means of a Rochon micrometer and a surveyor's compass, the relative positions of the various sections being determined at the same time. The writer is much indebted to the Rev. E. M. Burwash, of Toronto, for assistance in the prosecution of the survey. The topography north of the shore line is taken from a county map, and although it is not as accurate as could be desired, it will serve to show the relative positions of the various sections. In studying these deposits about thirty-five vertical sections were measured, generally by means of a hand level and jacob's staff, and of these, sixteen, at intervals of half a mile, are represented in the upper part of the accompanying plate. The cross section shown in the middle of the plate represents a continuous cross section of the deposits with a vertical exaggeration of ten.

Proceeding from east to west, at two miles east of Port Granby, a lower till is exposed in a low cliff. As we go west the cliff gradually increases in height. At the end of the first half mile this lowest till sheet is found to be overlaid by another sheet of an arenaceous till, which will be termed the third till sheet.* The eastern edge of this till sheet is well marked by a sudden increase in the height of the cliff; it continues inland as a low terrace. Half a mile further west these two till sheets are separated by about thirty-two feet of cross bedded stratified sands (Section 2). A short distance west of this section the sand beds immediately beneath the arenaceous till overlie a series of fine

* The characteristics of the different sheets of till will be described below.

PLATE I.—PLAN AND SECTIONS OF THE DRIFT DEPOSITS AT THE SOUTH OF THE TOWNSHIP OF CLARKE, DURHAM COUNTY, ONTARIO.

The Datum Line of the Sections is the Surface of Lake Ontario, May 20th, 1903.

textured stratified clays. These clays rest upon a narrow band of boulder till. Beneath this till sheet, which will be termed the second till sheet, are a second belt of stratified cross-bedded sands. Judging from the topographic expression of the cliff front, the till of the first or lowest sheet probably also occurs here above lake level. The second or middle till sheet extends along the shore for a little over a mile, and appears in Sections 3 and 4. At Section 5 it has disappeared; apparently both it and the underlying sand deposits were eroded before the arenaceous till of the third sheet was deposited, because the third sheet rests unconformably upon them.

What is regarded as the continuation of this second till sheet is again found about a quarter of a mile west of Section 8, there being an interval of a little over two miles between the exposures. The sheet with the stratified sands exposed both above and below it, may be traced westward for two miles, or to within a little less than two miles of Newcastle. The eastern part of this second sheet has a maximum thickness of twelve feet, as shown in Sections 3 and 4. The sheet reaches its maximum thickness of twenty-five feet a little to the east of Section 9. West of Section 9 the thickness gradually diminishes to about eight feet at Section 12. A little to the west of this the sheet apparently ends and the arenaceous till is found to rest upon cross-bedded sands (with thin beds of gravel), which are continuous with those beneath the second till sheet further east.

Half a mile east of Newcastle, midway between Sections 15 and 16, the cliff presents the following section in ascending order from present lake level :—

Upper till	Upper part substratified	5′ 9″	32′ 5″
	Lower part massive	26′ 8″	
Stratified Sands	Laminated argillaceous sands	6″	14′ 4″
	Sand free from clay	1′ 2″	
	Laminated argillaceous sands	2′ 8″	
Lowest till		....	1′ 0″
Modern beach		....	2′ 0″
			39′ 9″

The surface of the lowest till sheet which here shows above the lake level is gently undulating, and a few yards west of where the above section was taken it rises to six feet above lake level, while the thickness of the upper sheet has diminished.

The lowest till sheet lies below water level at Section 4 and at Section 7. At Sections 5 and 6 there is reason to believe that it is present

above lake level; but the base of the cliff is so obscured that this could not be proven. It reappears along the shore in several places west of Section 8, but as a rule the exact height of the upper surface above lake level could not be ascertained until within a quarter of a mile east of Section 13, where it is five feet. The height increases rapidly to thirty-two feet above lake level at Section 13. From here it gradually descends towards the west, passing below lake level west of Section 15.

Midway between Sections 10 and 11, three miles east of Newcastle, the following section was obtained :—

Upper till, arenaceous and substratified (third sheet)			8′
Sands, cross bedded			8′
Till, massive (second sheet)			12′
Sands and some gravel			16′
Till (intermediate sheet B)			11′
Stratified sands	Sand, moderately coarse	2′	12′
	Clays with sandy beds	9′	
	Sand, evenly bedded, coarse	1′	
Till (intermediate sheet A)			5′
Sands, cross bedded			11′
Laminated clays			19′
Measures partly concealed (probably first till sheet)			15′
			117′

In this section it will be noted that there are four beds of till exposed above the laminated clays which in several sections along the shore are found to overlie the lowest till sheet. The two intermediate sheets (A and B above) appear here between what have been termed the first and second sheets. The lowest of these sheets, A, has a thickness of five feet. It was not found in other sections on either side, and it is quite certain that its length in the cross section exposed along the lake shore is only a little over half a mile. It is probable that it reaches as far west as Section 11, but it could not be located on account of the talus cover. The next till sheet above this, B of the section, has a thickness of eleven feet. It also occurs in Section 11 with the same thickness. It is uncertain whether it is present in Section 10 or not. If so it does not extend much to the east of that section, and its total length in cross section is a little over one mile.

The uppermost or third till sheet is exposed continuously along the whole length of the Clarke section.

The Till Sheets.

The first or lowest till sheet consists of a fine textured and very compact clay in which there is a small amount of sand, numerous pebbles and small cobbles, derived chiefly from the underlying limestone, with a very much smaller number derived from the archæan rocks. Scattered through the till there are frequently found larger boulders and blocks, usually of gneiss, granite, or some of the associated rocks ; occasionally large boulders of the Trenton limestone occur. The boulders appear to be segregated in different parts of the till, there being long stretches nearly free from them between the localities where they are particularly abundant. The sheet has nowhere been found to present the slightest trace of stratification, even in the thickest sections. Wherever the bed rock is exposed this sheet is found to rest directly upon it. Its upper surface is undulating, so that at times it rises in dome-shaped hills above the surface of the lake, at times it lies below present water level. The maximum thickness observed in the lake-shore sections here described is about fifty feet.

The till of the second sheet, and of the two smaller sheets lying beneath it (designated A and B in the section given above), is almost identical with that of the lowest sheet, except that it seems to be slightly more arenaceous, the pebbles are smaller and less numerous, and boulders are almost wanting. The sheets preserve a very uniform thickness throughout their extent, being thus in very marked contrast to the lowest sheet, whose upper and lower surfaces are both irregular. The writer is inclined to regard the two small intermediate sheets of till as marking temporary and local advances and retreats of the ice sheet by which the till of the second sheet was laid down. In the field the actual ends (in the lake-shore section) of neither of these sheets could be located, although it is possible to assign a maximum length. The evidence available does not warrant the conclusion that they were of much greater extent and were eroded before the deposition of the second till sheet or of the sands immediately beneath it.

The uppermost, or third till sheet, differs much from any of the preceding. In many places it consists of two distinct portions, a lower part closely resembling the till of the lower sheet, and an upper part with a well-developed bedded character, and composed of a loose, sandy till in which there is but a small amount of clay. In the field it was not found possible to map the two portions separately. In places the two are very intimately associated. The clay portion will occur in

bands, varying in thickness from a few inches up to about two feet, with beds of the sandy till, often showing traces of stratification, both above and below it. At the point just west of Section 15 the sand and gravel lenses in the upper till sheet are separated by masses of clay from two to four feet thick. These sand and gravel beds are from one-half to two feet in thickness and about fifty feet or less in length. They are looped downward in the middle so that they appear in the cliff-face as if hung in great festoons. At times the stratification planes are found even in the clay portions of the deposit. Where the bedded structure is well developed it is often found to be remarkably contorted and twisted. Masses of the hard clay portions are occasionally found whose greatest dimensions, as shown in cross section in the cliff face, are vertical, and between them there will be found patches of cross-bedded sands. In the sandy portions of this till sheet there are often found large lenses of coarse gravel. One of these, four feet in thickness and several yards in length, appears to divide the upper till into two parts in the vicinity of Section 6, just west of Port Granby. About three quarters of a mile west of Port Granby, at Section 7, the upper till reaches the greatest thickness. Here gravel lenses, intimately associated with masses of unstratified clays, are particularly well shown, although the stratification, so evident in other parts of the section, is not so prominent a feature at this section. The sheet carries numerous pebbles and many boulders, chiefly of archæan rocks. Striated pebbles occur both in the bedded and in the massive parts of the till. There is a short section of the same sheet shown in the upper part of the cliff west of Port Hope. It seems not improbable that the bedded clays which occur three miles east of Cobourg and were described above may be contemporaneous with this till sheet.

STRATIFIED DEPOSITS.

At the base of many of the sections between Newcastle and Port Granby is found a series of fine unctuous, stratified clays, generally resting directly upon the first sheet of till. The thickness of these clays varies considerably, the maximum being about fifteen feet.

Conformably overlying these clays is a series of fine sands in beds varying from a few inches to several feet in thickness, and usually cross bedded (Plate II., Fig. 1). The maximum thickness of the beds of this first interglacial epoch, including the laminated clays above referred to, is about sixty feet. It varies locally, however.

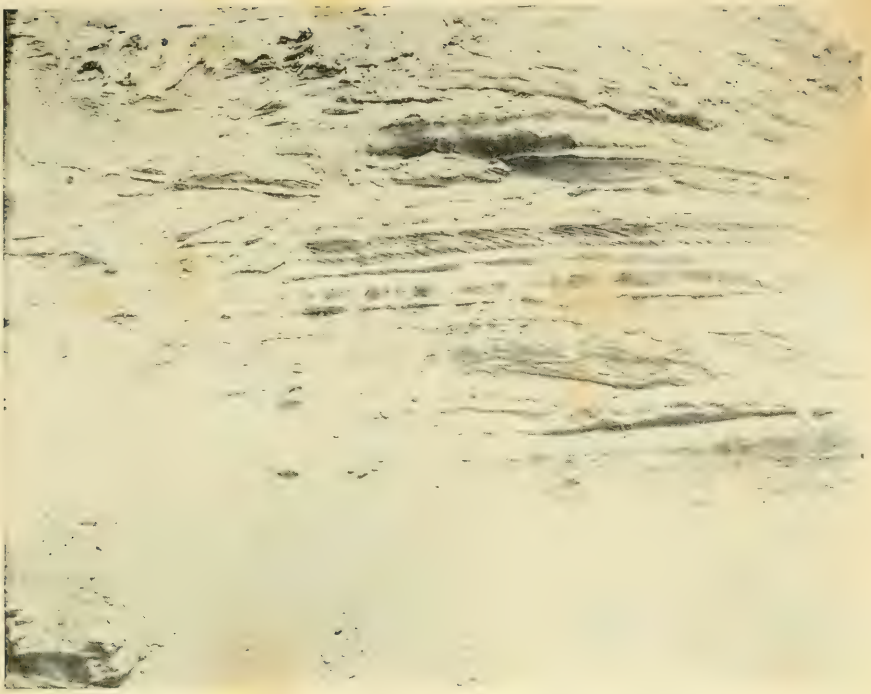


FIG. 1.—Cross-bedded sands of the first interglacial epoch of the locality. The small square micrometer target in the upper right of the picture measures one foot to a side.

FIG. 2.—The complex contact between the till of the third sheet of the locality and the underlying interglacial bed, from near Section 2.

The sands which occur between the two local till sheets (A and B above) are usually coarser than those of the first interglacial epoch, and they contain a few gravel beds. The series of cross-bedded sands of the second interglacial epoch, those overlying the second till sheet, are quite similar to those of the first epoch. The maximum thickness was found east of Port Granby to be fifty-six feet. This includes a few feet of stratified arenaceous clays found at the base of the section.

In none of the stratified deposits could any fossils be found.

In a few places, above the last till sheet, are a few feet of modern deposits—sand blown from the face of the cliff and lodged just behind the edge by the eddying current which exists there when the wind blows towards the cliff front. In one locality these sands have a thickness of five feet. They do not extend more than one hundred and fifty yards back from the front of the cliff.

Inland, north of the shore, there are stratified sands and gravels overlying the last till sheet, but none of them happens to be exposed in the lake-shore sections.

East of Port Hope, wherever stratified sands and gravels occur, they almost always are found to occupy the hollows between adjacent domes composed of the first till. Whether they belong to the first or second interglacial time interval it is impossible to say. As they are found, inland, to give place to till which presumably overlies them, and which probably represents the second till sheet, the inference is that they are contemporaneous with the sands of the first interglacial interval. West of Port Hope the sands are much thicker than elsewhere, and their position intermediate between the two till sheets is easily ascertained.

After the deposition of the sands of the second interglacial epoch there seems to have been an interval of considerable duration in which erosive processes cut broad valleys in the earlier deposits. In the vicinity of Port Granby one of these valleys reached a width of over two miles. A second, whose approximate width has not been determined, occurs in the vicinity of Newcastle.

The till of the last sheet follows the contour of the underlying deposits upon which it was laid down after their partial erosion. At the eastern end of the Clarke section it is found to rest directly upon the till of the first epoch. Elsewhere it usually rests upon the stratified sands of the second interglacial epoch. The relation of this till to the underlying sand deposits is in places very intricate (Plate II., Fig. 2). Sometimes

it appears as if large masses of the clay portion of the till had been forced down into the sands. In others the till has been laid upon the sands with very little disturbance. An uncomformable contact between the massive portion of this till sheet and the little disturbed underlying sands is particularly well shown near Section 4, half a mile east of Port Granby.

CORRELATION WITH THE SCARBORO SECTION.

Until the intervening section, forty miles in length, between that described here and the Scarboro section, has been studied in detail, an adequate correlation of the deposits in the two different localities is impossible. The lowest till sheet in the section here described, which has been shown to be persistent along the shore, with very slight interruptions for the forty miles, is probably the equivalent of one of the sheets in the Scarboro section. The absence of fossils in the interglacial deposits of the Clarke section makes it at present impossible to correlate these deposits with the interglacial deposits at Scarboro. Dr. A. P. Coleman regards it as quite probable that the lowest till sheet in the Scarboro section has no equivalent representative east of that section. The lowest till sheet of the Clarke section and eastward, he considers as the probable equivalent of the second till sheet at Scarboro, and the stratified non-fossiliferous beds immediately above this sheet would then be the equivalents of some of the upper series in the Scarboro section.

In the study of the Scarboro section it was also found that an erosion interval of considerable duration preceded the deposition of the second till sheet. In the section here studied in detail it is found that a prolonged erosion interval followed the deposition of the second interglacial deposits of the locality. It is quite possible that the sheet of till designated the second till sheet in this paper, may not be contemporaneous with any of the till sheets of the Scarboro section, but may merely mark an episode in the general retreat of the ice sheet previous to the deposition of the interglacial beds here regarded as of the second interglacial epoch. It would then be similar to the two intermediate till sheets designated A and B above, and would mark a somewhat larger transgression of the ice sheet. The evidence at present in hand is not sufficient to warrant a correlation of the deposits in the two localities on the assumption that these erosion intervals are contemporaneous and not successive; but, on the other hand, it may be noted that the occurrence of what may be three local sheets of till, separated by stratified

sands, will mark the position of the ice front at a time when interglacial beds of the equivalent time-interval were being deposited west of this at Scarboro and elsewhere.

The arenaceous substratified portions of the uppermost sheet of till differ greatly from the till of the second glacial epoch at Scarboro, but are similar to portions of the highest till sheets of that locality. In the more hurried examination of the entire one hundred miles of sections, made by the writer three years ago, these two till sheets were regarded as probably contemporaneous. The subsequent more detailed study has cast some doubt on this provisional classification. It seems advisable, however, to postpone further discussion until the study of the intervening section, now under way, has been completed.

HOW PLANT LIFE IS DISTRIBUTED IN CANADA AND WHY.

By A. T. Drummond, LL.D.

(Read 12th March, 1904.)

It helps us to understand the vastness of the territory included within the limits of Canada when we know that in proceeding northward from the United States boundary line we pass through, on the average, about 1,000 miles of forest or open country before we reach the point, within the Arctic Circle, where the trees, so familiar in our landscapes, entirely disappear; whilst, on the other hand, from Nova Scotia to Vancouver, differences in climate and physical conditions are so marked as to admit of three great distinctive floras, each keeping its own characteristic territory, each absolutely different from the other, and all within the Northern Temperate Zone. We are accustomed to look for wonderful changes in vegetation when travelling southward to tropical countries, but nearly as striking to the resident along the Great Lakes is the entire absence on the Western prairies of nearly all of the trees he has been so familiar with in Ontario, and their replacement further west, in British Columbia, by a large number of new forest giants some of which tower to heights not met with on this side of the continent. Trees most attract the ordinary observer, and this is natural because they are most striking in appearance and size, and commercially, form an important asset of the Dominion. On the other hand, on the Western prairies he cannot fail to be struck with the large splashes of colour due to the prairie flowers, which in the summer months everywhere brighten the dull green of the sward. These flowers, so characteristic of Manitoba and westward, find the forests, east of the Red River, a wall preventing their eastward distribution, whilst the Rocky Mountains, and sometimes even the dry western plains of the South Saskatchewan, form equally a barrier on the west. Thus, it does not require any scientific knowledge to see that, looking at Canada as a whole, and without regard to the United States, there are, apart from the wide spread but dwarfed plants which make up the Arctic flora, three great groups:—That included in the east and having its highest development in Ontario, that on the prairies of Manitoba and westward, and that in British Columbia, west of the Rocky Mountains. And the distinctions between these groups are as marked among the smaller flowers and shrubs as among their more giant congeners, the trees.

From a commercial standpoint, the trees are the most important. They are not only becoming increasingly valuable for cabinet ware, for construction purposes, and for export, but form a large source of revenue to Ontario, Quebec and other Provincial Governments. A knowledge of the range northward of trees is thus presently very important in connection with the construction and future traffic of the proposed Grand Trunk Pacific Railway. Certain trees are fair indicators of soil and climate, and are also essential to the settler, and important elements in the railways' traffic. The danger to be avoided is the location of the transcontinental route too far north where the more useful trees either do not grow or are at the northern limit of their growth. Lumber is very important to all of our Canadian railways as an item of traffic, whilst on the other hand, it enters largely into the necessary requirements of the settlers in construction of houses and bridges and the very many needs generally of farm life, and for these latter purposes it must be found near the line of railway if it is to be cheap. The projected route for the Government section would be about 300 miles north of Toronto and 200 miles north of Ottawa, but, long before these points have been reached, the red and sugar maple, all of the oaks, butternut, basswood, beech, ash, hemlock and many other valuable trees have ceased to grow, the elm is rarely met with, whilst the white and red pine have just found their most northerly limit and are very scarce. The prevailing forest includes chiefly black and white spruce, balsam-poplar, aspen, paper birch and Banksian pine, none of which have the value of white and red pine for structural purposes. For pulpwood, the demand for them and the direct revenue they will bring in must, in the future, be relatively small when compared with the vast available supply of these woods in this northerly country.

Looking at the forests alone, we can divide them readily into five areas, each of which may be appropriately named after the most prevailing and important tree within it, as follows:—Firstly, the Walnut Area which occupies the narrow south-west peninsula of Ontario bounded by Lakes Ontario, Erie and St. Clair, and has within it sixty-eight out of the seventy-six trees which are found in Ontario, including such trees as the Black Walnut, Tulip Tree, the Magnolia, the Sassafras, the Chestnut, Dogwood, Buttonwood and others; secondly, the Maple and Beech Area which occupies the country lying between Lakes Ontario and Huron, thence eastward between the St. Lawrence and the Ottawa Rivers to New Hampshire, and has within it about fifty-six different species of trees, including the Ash, Butternut, the White and Red Oak, Hickories and many others; thirdly, the White Pine Area occupying the country lying between Nova Scotia and Newfoundland on the one hand and the Winnipeg River and the Lake-of-the-Woods on the other, the northern

limit of this area curving in a southerly direction to the sources of the Gatineau and the shores of Lake Abittibi and then rising again to include Lake Nepigon, and having within parts of it many of the trees of the Maple and Beech Area although many are also conspicuous by their absence, especially in Nova Scotia, where there are altogether only thirty-three species of trees as against seventy-six in Ontario; fourthly, the White Spruce Area which includes the very extensive country between Labrador on the one hand and the Pacific Coast on the other, northward of the white Pine Area and the prairies and of about Fort Quesnelle in British Columbia to the extreme limit of the growth of trees near Ungava Bay, the Seal River on Hudson Bay and the mouth of the Mackenzie River, and having as its leading feature that practically eight species make up its vast forests, namely, the White and Black Spruce, the Paper Birch, the Balsam Fir, the Aspen, the Larch, the Balsam Poplar and the Banksian Pine; fifthly, the Douglas Fir Area which occupies nearly the whole of southern and central British Columbia to beyond latitude 55°, excepting the drier portions of the inland plateau, and includes forty-five species of trees of which thirty-four are, in Canada, exclusively within British Columbia or in the case of two or three, including the Douglas Fir, Black Pine and Western White Spruce, extend eastward somewhat beyond the foot-hills of the Rockies.

Taking, however, a general view of the whole flora of the Dominion, including herbaceous plants and shrubs as well as trees, we can readily distinguish the following marked groups:—

Canadian Group.—Embracing numerous species very generally distributed over the whole country from the Atlantic to the Pacific, and, many of them, northward more or less to the limit of growth of trees. They also occur in the Northern United States, but probably the great mass of the individuals of each species is rather in Canada than the United States.

Forest Group.—Comprising numerous species which range more or less from Nova Scotia and New Brunswick to the Rocky Mountains or towards there, but which appear to affect the forest country and to, more or less, avoid the prairie. The species of this group do not cross the Rocky Mountains.

Maritime Group.—Species confined to the immediate sea shore, some on the Atlantic, some on the Pacific, and others common to both seashores, although several of them are also found along the Great Lakes and in the neighbourhood of saline ground farther inland.

Eastern Coast Group.—Comprising plants confined in range to the eastern portions of the Province of Quebec and to the Maritime Provinces of Nova Scotia and New Brunswick, although this large area is more conspicuous by the absence of numerous species common in Ontario and Western Quebec than by the presence of a distinctive flora.

Erie Group.—Including the large number of middle temperate plants found in the south-western peninsula of Ontario, and common to that area and to South-western New York, and to Ohio, Pennsylvania and other Middle States of the Union, whilst some come from farther south.

St. Lawrence Group.—Embracing numerous species distributed generally throughout the St. Lawrence valley and lake region, but not ranging west of the wooded country immediately beyond Lake Superior and Lake-of-the-Woods.

Boreal Group.—Including in this those northern species which occur on the mountains and near the shores of the Lower St. Lawrence, around the northern coasts of Lake Superior and among the mountains of British Columbia. They generally occur where cold and deep waters of the sea or lakes or sufficient altitude supply a moderately low temperature.

Ontario Group.—Representing a considerable class having its maximum development in Canada in the central and eastern portions of the Province of Ontario, but also occurring in the eastern and middle sections of the Province of Quebec, and southward in the New England and Middle States.

Prairie Group.—Embracing species familiar more or less over the whole of the prairies of Manitoba and north-westward, but probably of limited range over the dry prairies of the western and south-western sections of Assiniboia.

Western Plains Group.—Including species belonging to the dry prairies and plains of the North-West Territories where the rain fall is limited, and extending almost to the foothills of the Rocky Mountains. In British Columbia in the valleys of the Fraser and Thompson Rivers north of Lytton onward to about latitude 53°, and again in the districts surrounding Okanagan Lake and to some extent in the Eastern Kootenay and Upper Columbia River districts the precipitation is deficient and the dry country plants again appear.

Rocky Mountain Group.—Embracing the numerous plants, not alpine, which in our present knowledge of their range are confined to the valleys and foothills of the Rocky and the Selkirk Mountains.

British Columbia Group.—Comprehending all those species which are distributed somewhat generally over, but confined to, the middle and southern sections of the Province of British Columbia.

Southern British Columbia Group.—Including under this the more southern plants found in British Columbia, and whose range northward, from Montana, Idaho and Washington Territory, has been facilitated in some cases by the drier climate of the interior and in others by the general direction of the valleys in the Rocky, Selkirk and other mountain ranges there.

Cascade Group.—Embracing a well marked assemblage which is confined to the westerly side of Vancouver Island and to the vicinity of the Cascade range of mountains on the main land.

Arctic Group.—Comprising a few rare representatives in the Alpine districts of New England, and on the Mingan Islands and Island of Anticosti and neighbouring coasts, but as a rule confined to the high northern coasts of Labrador and Hudson Bay, and to Greenland, the shores of Baffin's Bay, the Arctic Islands and Lower Mackenzie River country, and to the higher peaks of the mountains of British Columbia.

European Group.—Comprising an extensive flora common to Europe and Canada and in many cases extending to Japan and Manchuria.

The causes which give rise to these various groups, may be classed as *general*, affecting each one of them, and producing similar influences in other countries; and *special*, resulting from sets of circumstances peculiar to Canada or due to natural conditions prevailing there, either now or in past ages. After all our thought, however, there remain anomalies hard to explain and that will always afford food for speculation.

General Causes of Distribution.

The general causes, still in force, which have affected distribution are well known. River, lake and ocean currents, play their part in every section of the globe, not only in dispersing the seeds of aquatic plants, but also those of land species, which constantly come into connection with the water. The seeds are blown into the water and are carried sometimes long distances before they are again thrown upon the land by the waves. Thus, southern forms find their way northward, and northern forms meet with suitable localities farther south where the mass of water is sufficiently large to produce a cool, equable temperature. Particularly would this be the case in Canada where the water communications are on such an extraordinary scale, both on the coast line and along the Great Lakes and rivers in the interior of the country. Great mountain ranges, again, besides attracting moisture, form barriers to the distribution of plants, but on the other hand, as on the Rocky Mountains, provide facilities on their peaks, for the range southward of the Arctic flora. Birds form a constant source of distribution, going on for ages past. That seeds and fruits are the especial food of birds, that birds not only traverse great distances in search of food, but large numbers of them have semi-annual migrations, that the peculiar habits of birds lead them into situations where seeds may adhere to their feathers or in mud to their legs and feet, and that great numbers of seeds are for the purpose of diffusion supplied by nature with means of adhesion to objects, whether birds or quadrupeds, with which they are brought into contact, are all

of them circumstances in progress for long centuries past, the one fitting into the other, which have been instrumental in the gradual and wide dispersion of many plants. The popular view of the economic purposes of fruits is that they are provided by nature as food for man and the lower animals. Perhaps an even more immediate purpose in their colour and flavour, is that they may attract birds and quadrupeds—as the colours of flowers do insects—and that the seeds, by being carried great distances in the crops and stomachs of these creatures, should thus have an important means of diffusion.

Wind is, however, the most important factor in distribution. Many plants have their seeds furnished with appendages to be utilized in connection with the wind, and such plants have a generally wider distribution than those not so furnished. The different species of maple, ash and pine, have what might be termed wings attached to their seeds, and these are undoubtedly thus provided that, in falling at maturity, the seeds may be carried by the wind beyond the parent tree. The seeds of most of the Compositæ are supplied with plumes or awns which form an important means by which they are distributed, and thus this, in America, most extensive of the phænogamous orders is, though geologically recent, of wide diffusion. Whilst, however, the ordinary winds have their local effects in scattering seeds, it is to hurricanes and tornadoes, and even ordinary high winds that we must look for the carrying of them to great distances. It is not difficult to suppose that most seeds can be so carried. Where the fruit is heavy, as in the case of oaks, hickories, walnut, butternut, chestnut, plum and cherries, the range of the species is relatively circumscribed. The seeds of herbaceous plants are, however, as a rule light, almost feathery, in weight—a circumstance which, like the awns and wings provided as appendages to many of them, has been, without doubt, so arranged by nature that they may be readily distributed at maturity by the wind. The power of the wind as a distributor of the lighter class of seeds has been underestimated. The rapidity with which new railroad tracks, extending into newly settled as well as old settled country, have become tenanted, not by plants from the neighbourhood, but by roving introduced plants, is a striking evidence of the action of winds. Most of these introduced plants, so common in cultivated fields, on roadsides and on compost heaps, as well as on railroad tracks, have seeds relatively light in weight, and provided in many instances with appendages to facilitate their dissemination. In districts where the forests have been burned over, the native plants with which the burned area is soon peopled, are generally of two classes —berry-bearing shrubs, the seeds of which have been deposited by passing birds, and plants like the fire weed (Epilobium), birch trees and willows, whose seeds have wings or awn attachments, which not only

prevent them from too quickly reaching the ground when they fall at maturity, but also afford a better opportunity to the wind to carry them to great distances. And these distances are not to be measured necessarily by an acre lot or even the breadth of a township. Volcanic dust, forced from a volcano during eruption may float through the atmosphere for many hundreds of miles before descending. What may not be possible with light seeds when a gale of wind prevails ? The great range of so many sub-arctic and boreal lichens, also found on most high summits in middle and even southern temperate countries, seems likewise, an evidence of the power of the winds in carrying spores to enormous distances.

The question, however, here naturally suggests itself—Why are many species of wide range, reaching from one side of the continent to the other, whilst so many others are circumscribed in area? All of the general causes indicated have been important factors in the extension of the range of plants, but there is another and general conclusion, the drawing of which analogy warrants. It may be regarded as the innate aggressive energy in such species or the lack of this energy. Every plant may be said to have an area where its numbers and its life energy are at the maximum. Outside of this area, the individuals are found, diminishing in numbers as they extend, until they finally cease on every side. The growth, again, of each individual plant, has its birth in the swelling seed, its maturity when it expands its flower, and its death when, after ripening its seeds, it withers and decays. Similarly, each species, as such, has had its beginning in past ages, in the development and permanency of a well defined variety formed from an already existing species. This new species, thus formed, would, in the course of downward geological time, reach its highest stage of existence as a species; its period of most active growth and of largest area of distribution, when its ability, under new surrounding conditions, to give rise to further new species, is greatest. Finally, such species has, in downward geological time, its period of decline, when with perhaps changing environment, its innate energy as a species is diminishing and its areas of distribution being gradually curtailed, until extinction comes, leaving to the palæobotanist the duty of revealing its story when he discovers the remains in the clay nodule or the hardened rock. Applying this idea, the older existing species, which are at their maximum of activity, would, with the greater opportunities which in time they had had, have naturally a wider range, under the same set of circumstances, than those which were of more recent creation. Others, again of the older species, would have passed their maximum of energy and, even though wide of range, would, in each passing century, become more rare. The species of newer creation would, on the other hand, be gradually extending their range wherever circumstances of climate and situation admitted,

but, from the shorter lapse of time, would have a more limited range than the older species. Thus, for illustration, *Viola Selkirkii*, Pursh, being common to Europe, Asia and America, is probably one of the older species, but being now rare on this continent, may presently be on the decline; *Viola blanda*, Willd, which is a frequent species of wide range, is doubtless about its maximum of energy; whilst *Viola hastata*, Mx., a third individual of the fifty species of violets now recognized in Canada, is uncommon, and may be either a recently formed species, or an older species on the decline.

SPECIAL CAUSES OF DISTRIBUTION.

Whilst there are general causes operating more or less in all countries which are now affecting the distribution of plants over Canada, there are numerous special causes arising from the relative influence on climate of great masses of land and of water; insular position, ocean currents, enormous sea coast lines, great or limited rain fall, the prevalence of fogs, the direction taken by chains of lofty mountains, the dryness of the atmosphere in elevated situations, the great stretch of treeless prairie, the breadth and the cooling effects of the immense and deep inland lakes, the longer daylight in the summer months and the cooler nights, and what might be termed the companionship among plants, all of which, in addition to the conditions which were at work in geological periods, now long past, have, each in its own area, among other causes, influenced the grouping of plants in different parts of Canada.

In illustrating the effect of these forces in producing groups, it is impossible, where the area to be covered is so wide, to more than state the facts without going into details or discussing debatable points.

Whilst in the Canadian Group the species are all of wide range, extending generally from the Atlantic to the Pacific, none are exclusively Canadian, but a large number have their maximum distribution in this country rather than in the United States.

The species forming the Forest Group also occupy a wide area. That in the far west so many of these plants avoid the open prairies, is an illustration of what might be termed a companionship which nature has arranged between many of the smaller forms of plant life and their towering congeners, the trees, and which brings to light the dependence of the former and the protecting influence of the latter. Amidst the great bluffs of trees which margin the prairie, the general temperature is modified, the nights are warmer, the play of the sun's rays on the smaller plants is more limited in extent and continues for a shorter time, the ground itself is more moist, and the high, drying winds of the prairies

are greatly diminished in force. Whilst the smaller representatives of plant life find within the line of forests or bluffs such congenial conditions, they afford, as they die, some return to the trees by joining with the trunks and leaves of these trees in enriching the soil by their decay.

Whilst there are natural changes in climate and consequently in vegetation arising from increasing nearness to the Arctic Circle, other important factors which influence the range of trees and the smaller plants in Northern Canada, east of the Rocky Mountains are the relative masses of the land and the water, the direction of the great mountain chains, which here somewhat parallel the Pacific coast, and the much lower altitude above the sea of the Peace River country east of these mountains. The effect of the great breadth and length of that cold inland sea, which we call Hudson Bay, is very marked. On the east side, the trees are sparingly met with on the coast until they disappear entirely immediately beyond Richmond Bay. On the Atlantic side of Labrador, the growth of trees on the coast line is directly affected by the wide Boreal current which comes south through Davis Straits, and the last trees on the coast are met with at about Hamilton Inlet. Far inland, however, between Hamilton Inlet and Richmond Bay, away from the influence of the sea, three or four species range farther northward for 200 miles. Again, on the west coast of Hudson Bay, the last trees seen are immediately beyond Fort Churchill, but inland, beyond the influence of the bay, the northern limits of the forest country run north-westward from about this point towards the mouth of the Mackenzie River. The great mass of the land in this direction results in a more moderate climate, which improves as the numerous lakes and muskegs are left behind and the Slave and Peace Rivers are reached.

The enormous coast line of Canada fronting on the Pacific and again on the Atlantic Ocean, with the Arctic Sea between, has led to the occurrence of sea shore plants exclusively confined, some to the Pacific and some to the Atlantic coast, whilst others are common to both. Quite a number of these sea shore plants are also now found along the shores of the Great Lakes and on saline ground farther westward. They are evidently the remains of a larger maritime flora which margined the interior coast in Pleistocene times when the ocean made great inroads over the Province of Quebec and up the Ottawa River. The fact of their flourishing now on the lake coasts and inland shows how they have, but in greatly diminished numbers, adapted themselves to new conditions in which, in the one case, the saline element, and in the other, the moist atmosphere of the seashore, were wanting. That the larger number of these inland seashore plants are found around Lake Ontario

and smaller sheets of water to the east and south of it—all of which were close to or formed part of the Pleistocene seas—is confirmatory than otherwise of the origin of the remarkable range of these plants. If this hypothesis be correct, these inland sea shore plants can be regarded as one of our older floras, dating back to the times of the Leda clays.

The most remarkable feature in the eastern coast distribution is the absence of such a large number of the familiar trees, shrubs and herbaceous plants of the Upper St. Lawrence valley. The Appalachian chain of mountains has no doubt acted as a barrier to the western progress of many plants, as it has to the eastern extension of many others. The lower temperature, the moister atmosphere and the prevailing fogs, so pronounced on the immediate coast, especially of Nova Scotia, New Brunswick, Newfoundland and the St. Lawrence estuary, must exercise considerable influence inland as well, though this influence necessarily diminishes as the distance from the coast increases. Again, the cold Labrador current, by a branch through the Straits of Belle Isle, extends its influence up the St. Lawrence on both sides towards Quebec, whilst its main stream, after washing the eastern coasts of Newfoundland, spreads along the Nova Scotia and New Brunswick coasts in its course south-westward. Of the effect of this broad cold current on plant life on the immediate coast, there is no question. The insular character of Nova Scotia and its elongated shape would rather intensify than otherwise these effects on plant life within it. We miss in this province the basswood, the ironwood and all of the hickories and have only one species of elm, one of ash and one of oak, whilst the white cedar is unknown through most of the province.

We can readily account for the large and important representation of plants found immediately north of Lake Erie. This section of Ontario is not only farther south than any other part of Canada, but practically forms a peninsula with all the advantages of a peninsular climate. It is in the latitude of Western New York, and, in part, of Northern Pennsylvania and Northern Indiana and has within it most of the plants of these states. Lake Erie would form in one respect a natural barrier to continuous northward range of southern plants but on the other hand the currents and the winds of Lake Erie facilitate this range to a considerable extent. On the Pelee Islands, and on Point Pelee and other jutting headlands on the north shore, there are met representatives of the more southern flora of Ohio and Indiana. Another interesting feature is that in the counties bordering Lake Erie the trees are very well distributed. It is possible to find on a single farm of 200 acres, more than half of the species of trees which occur in Ontario.

It is a remarkable fact, that a considerable number of forest trees of Ontario in their range westward, come to an abrupt termination in Canada in the district lying between Lake Superior and the Lake-of-the-Woods, whilst others are hardly seen west of Sault Ste. Marie. In Ontario there are seventy-six species of forest trees, of which thirty-six are known either on the north or the south shores of Lake Superior. Of these thirty-six, only thirteen cross into the prairie region in central and southern Manitoba. Similar circumstances are apparent in an even greater degree among the shrubs and herbaceous plants. In Canada, many of these seem to be limited in their western course by the outlet of Lake Superior, though in the United States they may be found to the southward of this lake. Lake Superior is a large body of cold water whose surface at fifty miles from land, has been found even in July, to have a temperature as low as 39½° Fahrenheit. In this respect it is quite different from the other lakes. The effect of this low temperature on the vegetation of the immediately surrounding land is very marked, making it a suitable home for some semi-Arctic plants. Further reasons for this limit in westerly range are readily understood when the rocky, hilly nature of the country around the northern coasts of this lake and the more boreal character of the climate generally there, are considered.

The rough nature of the country immediately to the westward of Lake Superior—being successions for over 300 miles of rocky hills, swamps, and large and small lakes with their connecting rivers—has had, no doubt, its influence in limiting the distribution of many species there. It, however, appears also suggestive that the gradual widening in the past by forest and prairie fires, of the prairie area in a direction easterly from the Red River, has been a leading cause in checking the farther westward extension of so very many of the eastern trees, shrubs and herbaceous plants presently found in the country to the east of the Lake-of-the-Woods.

The interesting points in the Boreal Group are the occurrence of some of the species on the Lower St. Lawrence coasts and, again, around Lake Superior. In both cases these semi-Arctic or high northern plants are found, not on Alpine summits, but at or near the water level. Reference has already been made to the influence on plant life, especially on the northern shores, of the cold deep waters of Lake Superior, an influence that does not extend very far inland and suggests whether the semi-Arctic plants found on the immediate coast may not be the relics of the Arctic plant life which in Pleistocene times or previously, no doubt, occupied this region. On the Lower St. Lawrence we find a similar representation of high northern plants. The cold and broad Boreal current which skirts the Labrador coasts sends a branch through the

Straits of Belle Isle, up the north side of the estuary of the St. Lawrence. At Murray Bay the temperature of the water in August at a mile off the land registered on the surface 46° and at eighteen fathoms only 38½° Fahrenheit. Semi-arctic plants are found here and at Tadousac, as well as farther down the estuary. On the south shore at Cacouna and Metis the water is less cold, without doubt due to the tempering influence of the fresh waters of the St. Lawrence, which mingle with the colder Boreal current, the two then proceeding outwards to the gulf by the south shore.

The flowers confined to the prairies probably constitute our youngest group. The area within which they are found is the most recently formed, geologically speaking, and around Lakes Winnipeg and Manitoba may be said in places to be still in process of formation. The absence of plants familiar in other parts of Canada is just as striking a characteristic of the prairies as the presence of new forms there. Whether the whole prairies have been at one time covered with forest, may be open to question, but there is a strong probability that to forest fires, constantly recurring, may be attributed the gradual enlargement of the prairie area and the formation of new prairies. It may be objected that were this the case, the stumps and roots of trees should be found on the surface of the prairie. They are, however, sometimes found and that they have not been more frequently observed is probably due to the rapid decay—one authority gives four years—of the stumps of the poplar, the almost universal tree of the prairies and the immediately surrounding forests.

The influences at work to give individuality to a plant on the prairies are very striking. The rainfall is light, the atmosphere is dry, the play of the winds is uninterrupted, there is a general absence, except in the river valleys, of the protecting influence of the trees and thus to each plant there is a greater supply, and a longer period, of light during the summer months, the nights are cooler, there is generally a uniform soil, often a black or sandy loam, over large areas of country, and there is in the vast expanses of level or relatively level plain, an entire absence of marked physical surroundings. Why should not all this environment have its influence on the individuality of plants just as we find that the distinctive features of countries have their effect in helping to mould the characters of their people ?

The longer light during the day and the cooler nights have had even more to do with the high standard of the wheat grown in Manitoba than the magnificent fertile soil. It seems to be a rule that the nearer wheat is grown to the most northerly point where such growth successfully is possible, the better is the wheat. This may prove to be a rule

of more general application to timber, grains and fruit than we have supposed. Canadian barley was so preferred by the Americans that a prohibitive duty had to be imposed to keep it out of their country; apples from Montreal and Abbotsford are noted for their quality; Montreal melons are considered a delicacy at the New York hotels; Quebec strawberries used to be famed for their size and flavour; the wood of the poplar which is considered by the Ontario farmer of little value, is found in the more northerly climate of the North-West Territories, a more useful wood. It is very suggestive that these are but illustrations of what may, on investigation, prove to be a rule with our timber trees and agricultural products. In this more northern climate may not our woods be more suited for construction purposes and cabinet ware than those grown farther south? The suggestion is made from analogy, but it is well worth careful investigation.

The westerly portion of Assiniboia and parts of Alberta are different in appearance from Manitoba. We meet with less of the flat prairies and more of the dry, somewhat rolling, plains, and we come across plants which remind us of Montana, Wyoming and Utah. Irrigation is necessary if much of the country of the South Saskatchewan is to be always available for agriculture. Even near the foothills of the Rocky Mountains, in the valley of the Milk River, the Cactus, the Sage and the Greasewood, characteristic plants of dry somewhat arid regions, are met with, whilst to the northward around Calgary, the country is more suitable for ranching purposes than for the growth of cereals. The successive, practically unbroken chains of lofty mountain ranges interposed between this district and the Pacific Ocean have, as the air currents pass eastward across them, attracted the moisture laden clouds, leaving but a light rainfall for the plains on the east side of the Rocky Mountains, whilst, as Professor Stupart suggests, the drying effects of the Chinook winds have had much to do with preventing the spread of trees over this vast area. This, however, does not explain the fact that whilst these plains are semi-arid, there is farther north, amidst the foothills of the mountains and in the North Saskatchewan and Athabasca River country, sufficient humidity for agricultural purposes. Probably this may be due to the air currents, near the boundary, having to cross in succession the mountains on Vancouver Island, the Cascades, the Selkirks, including the Gold and Purcell ranges, and finally the Rocky Mountains, before reaching the plains, whilst across the Pacific Ocean to the Yellowhead pass, these air currents would have fewer peaks to carry off their moisture.

These same chains of mountains, with the Japanese current and the direction of the low pressure air currents from the Pacific Ocean

have, however, a remarkable effect on the climate and productions of British Columbia. Only within the past year or two has our knowledge of the flora of this, the most westerly province of Canada, reached a point where it is possible to indicate, with a reasonable definiteness, the geographical distribution of its flowering plants. Perhaps in no other country are there so many varied physical conditions affecting this distribution. Four great mountain ranges, the Rockies, the Selkirks (including the Purcell and Gold ranges), the Cascades, and the Vancouver and Queen Charlotte Island ranges, traverse more or less the length of the province in serrated ridges somewhat parallel to the Pacific coast, and between the ranges on the mainland are extensive, highly elevated, rolling plateaus, and long river valleys. By standing directly in the path of the low pressure areas crossing British Columbia from the Pacific coast, these ranges result in very greatly increased precipitation on their western slopes, whilst to the immediate eastward of them, the very limited moisture leads more or less to irrigation being necessary and to the presence of plants from the arid plains to the south. Apart from the marked effects of the excess or deficiency of the precipitation on the character of the vegetation—effects often seen within a few miles of each other—the great heights to which the peaks of the Rocky Mountains in unbroken succession rise, form barriers to eastward and westward distribution, whilst, on the other hand, the long river valleys, as those of the Kootenay, the Columbia, and the Fraser, lying between the mountain ranges, facilitate the northward course into British Columbia of plants from Washington, Oregon and even from Nevada and California. On the coast, the Japanese current which off Vancouver Island has registered as high as 54°, plays a strong part in modifying the climate, and during long ages past has no doubt been one of the means by which Asiatic plants have been introduced into America.

The groups into which British Columbia plants may be divided have some points of special interest. The seashore plants comprise over forty species, but of these, eighteen are common in Canada, to both the Atlantic and Pacific coasts, and at the same time are, with two exceptions, also found in Europe, and in a few cases, in Japan and Manchuria. This wide, disconnected range would suggest that they form an older flora than those confined to the shores of the Pacific Ocean.

The large and well marked assemblage, referred to here as the Cascade Group, is confined in its range, more or less, to the westerly side of Vancouver Island or to the vicinity of the Cascade range of mountains on the mainland. The vegetation there is largely influenced by the great precipitation which prevails, and the milder climate arising from the Japanese current. The rain and snow fall at Cape Scott in 1902

reached 135 inches and at Clayoquot 146 inches, whilst in other places on the west coast of Vancouver Island this precipitation has averaged 112 inches. On the mainland at Vancouver (city) it reaches sixty inches and at Port Simpson ninety-three inches. Whilst this humid climate prevails on the west side of the coast range, on the east side, especially in the valleys of the Fraser and Thompson Rivers north of Lytton, onwards to about Alexandria near latitude 53°, and in the districts surrounding Okanagan Lake and to some extent in the eastern Kootenay and Upper Columbia River districts, the precipitation is deficient and irrigation is necessary. The annual rain and snow fall together vary on the average from ten inches at Midway and eleven inches at Kamloops to seventeen inches at Chilcotin and eighteen inches at Tobacco Plains. The dry climate has led to the appearance of some of the plants of the semi-arid sections of California and Nevada.

That a large number of plants very familiar in Oregon and Washington and some in California should find their way to the immediate northward of the British Columbia boundary line, their range being facilitated by the direction of the mountain ranges and the river valleys, and the mild climate in these valleys, would be anticipated. One of the remarkable features, however, of, in great part, the southern half of the province, is the very large number of northern temperate plants which, in Canada, are exclusively British Columbian. They have originated on the milder and more humid plateaus and valleys west of the Rocky Mountains, and, with this great mountain range, as well as the treeless plains and dry climate of Alberta, as barriers to keep them there, they have remained a peculiarly western flora. Towering trees as well as shrubs and herbaceous plants are included in the group, and not a few of them may be regarded as representatives of kindred species in eastern Canada. In age, the species of this group are younger than the general Canadian flora and date their gradual evolution from a time when the raising of the great mountain ranges and inland plateaus created new conditions of humidity and dryness, light and shade, heat and cold, broad river valleys and high elevations above them, and the association of the smaller plants with forests of a more lofty type and so often amid rugged surroundings.

Another interesting assemblage has been referred to as the Rocky Mountain Group. The general elevation, the rugged environment, and the very ample precipitation on the western sides of the Rocky Mountains and the Selkirk range, although falling very short of that on the British Columbia coast, has resulted in conditions on the lower slopes of these mountains favourable to very many plants which at the same time are never found near the more humid, milder coast. The precipitation

is less near the United States boundary line than farther north, due to the more numerous mountain heights commencing with the Vancouver Island range which intercept the moisture laden clouds on their way across British Columbia from the ocean. The plants of this group do not range east of the Rocky Mountains.

PLANTS COMMON TO EUROPE AND AMERICA.

That there is a considerable resemblance between the floras of Canada and Northern Europe and again between the floras of Canada and of Eastern Siberia and Japan, is well known. Including the Horsetails and Ferns, probably about 575 species are common to Canada and Europe, and, again, probably nearly 350 are common to Canada and Japan or the River Amur country. A large number of these in turn are common to the three continents or are represented by varieties which have, no doubt, their origin in the changed environment. The hypothesis, generally accepted, has been that in some comparatively recent epoch there had been a connection between Europe and America which had facilitated the intermingling of the plants of the two continents. The late Professor Asa Gray, of Harvard University, however, suggested the probability that the migration of European plants had taken place across Asia to America. I have not been able to follow the conclusions of others on this subject. The peculiarities in the range in Canada of these Asiatic and European species, the identity of many of the fossil plants found in the Pleistocene clays in Canada with plants now existing on the three continents, and the older look of this northern part of the American continent, all seem rather to suggest that whilst there may have been facilities for migration to this continent both in an easterly and westerly direction, Canada was the point of origin of many species now common to Europe and America. There are numerous European species in the eastern half of Canada which are unknown to the western half and yet are represented in Eastern Siberia and Japan. How can this immense gap be accounted for? Again, there are other European species similarly limited to the eastern half of this country and which do not occur in either Siberia or Japan. This is also an anomaly. The argument of range is somewhat lengthy and will not be gone into here. It has, however, been supplemented by geological discoveries in recent years, for instance, of over seventy fossil plants in the Pleistocene clays of Toronto, Ottawa and elsewhere. Of these, twenty occur at the present day in both Europe and Canada, fourteen are similarly Asiatic and Canadian, whilst eleven are common to the three continents. This, if it does not indicate that in Pleistocene times the intermingling of American, Asiatic and European forms had already beeen effected, at least shows that in

this earlier period of our history, these species were present in Canada, and we can assume that they had here their place of origin, if there is nothing to indicate their presence at as early a period in Europe. Still further, in the vast areas of exposed Laurentian and Huronian and other early formations, Canada has an old look and must have furnished a home through the long past ages for the growth and diffusion of northern temperate plant life when other sections of the globe have from time to time been under water. We may very reasonably conclude that here may have been the point of origin of many of these plants common to the two continents. There is even some direct evidence that in later Cretaceous times the relations of land and water must have been such as to allow migration between Europe and America.

Age of Canadian Flora.

There are, it will be seen, some data on which to found opinions on the ages of some of the groups which make up our Canadian flora. The species, of whose presence in the early Eocene times there is some evidence, are the oldest known representatives of the existing flora. Next to these in age, as species, are the plants common to Europe and America, for they were already well distributed at the time of the deposition of the clays of the Ottawa and the Don Rivers. It is probable that many of the Arctic species may be equally old, whilst the American species, not also European in range, but which are denizens of Japan, may be contemporaneous or even earlier in origin. The hazel and the sensitive fern, for example, both now common to Canada and Japan, were known plants in the United States in Eocene times. The plants confined to British Columbia and southward form probably a later flora brought into existence after the first upheaval of the great mountain ranges there. Following on these older floras, but possibly contemporaneous in age with some of them, are the Boreal species on the headlands of Lake Superior, and the maritime plants, presently on the shores of the Great Lakes. The more recent creations are, without doubt, those species—well represented by Compositæ—which frequent more especially the newer prairies of Manitoba and the North-West Territories.

The vast changes which took place in Canada during tertiary and subsequent times suggest the struggle for existence which must have prevailed among the plants of these periods. What destruction of animals as well as plants these changes must have occasioned! What adaptation to new conditions in which the survivors found themselves, must have resulted! What innate energy must have existed in the relatively few survivors of the earlier periods, which has enabled them to carry out all their functions of growth and reproduction during all these successive geological eras down to the present day!

INTERNATIONAL ARBITRATION.

By J. M. Clark, M.A., LL.B., K.C.

(Read 22nd March, 1902.)

No apology is needed for bringing such a subject before the Canadian Institute. International Arbitration has undoubtedly become a recognized branch of international law, the title substituted by Bentham for the equivocal phrase "Law of Nations."

International law has proved its right to be included in the great science of jurisprudence which was defined by Justinian as "the science of things human and divine, the knowledge of the just and the unjust."

In addition to its scientific interest, international arbitration has for Canadians a peculiar importance of a very practical nature, and it is therefore specially fitting that the subject should be carefully studied by such a body as the Canadian Institute.

We often hear arbitration referred to as a modern institution, but there is no foundation for this claim. The Greeks not merely advocated but practised international arbitration. One instance may be referred to —Athens and Megara after a bitter contest for the island of Salamis, the possession of which had been recovered by Solon, agreed to refer their dispute to the arbitration of Sparta. Five Spartans were appointed to determine the question at issue and after hearing the evidence adduced by the parties to the dispute, the arbitrators rendered their verdict in favour of the Athenians, and the Megarians accepted their award. Archidamus, King of Sparta, is said by Thucydides to have declared that it was unlawful to attack an enemy who offered to answer for his acts before a Tribunal of Arbiters.

Arbitration was an important part of the Roman law. Very few either of the advantages or the disadvantages of arbitration, as developed in modern times, escaped the trained legal minds of the Roman jurisconsults. Indeed, the earliest type of judicial proceeding among the Romans was a mock combat followed by a reference to arbitration. The first judges were simply arbitrators, and civil jurisdiction was developed out of arbitration.

There is not time to trace in detail the history of the development of arbitration as a means for the settlement of international disputes, in order to ensure that universal peace for which in all ages there has been

a desire. The Greeks dreamed that Astræa, the star-bright maiden, who, having tarried longest among men, withdrew at the termination of the golden age to be placed among the stars, would return to earth to end the discords and turmoil of mankind, and inaugurate an era of perpetual peace.

The twentieth century has come and men have not yet beat their swords to plowshares nor their spears to pruning-hooks. It can not yet be considered prudent for a nation to learn war no more.

One has still to dip into the future, far as human eye can see, before one can perceive the progress of common sense,

> "Till the war drum throb no longer and the battle flags are furled
> In the parliament of man, the federation of the world,"
> When
> . . . "the common sense of most shall hold a fretful realm in awe,
> And the kindly earth shall slumber, lapt in universal law."

Though many over-sanguine expectations have been disappointed, a study of the development of the principle of international arbitration leads to the conclusion that real and substantial progress has been made. It is always well, however, to look the facts squarely in the face.

The closing of the Temple of Janus by Augustus was followed not by peace, as was anticipated, but by the overthrow of Rome by the Barbarians.

The great International Exhibition of 1851 was trumpeted as a call to loose "from growing commerce" her latest chain

> "And let the fair white-winged peacemaker fly
> To happy havens under all the sky,
> And mix the seasons and the golden hours;
> Till each man find his own in all men's good
> And all men work in noble brotherhood,
> Breaking their mailed fleets and armed towers
> And ruling, by obeying Nature's powers."

Yet that feast of wonder was scarcely over before three of the great European nations were at war; and since then war has not been long if ever absent from all the continents.

To all this it must be said that evolution is a slow process.

It took a long time to establish the jurisdiction of our civil courts. Even as late as 1818, in the famous case of Ashforth v. Thornton,

(1818), 1 B. and Ald. 405, Lord Ellenborough, C. J., laid it down that the general mode of trial by law, in a case of appeal, is by battle, at the election of the appellee, unless the case be brought within certain exceptions not necessary to be here referred to. This mode of trial introduced into England by the Normans remained the law of the land until 1809, when it was abolished by 59 Geo. III. ch. 46.

Though one cannot discuss in detail the various schemes from time to time propounded for the peaceful settlement of international disputes, one may be permitted a passing reference to the proposal of Leibnitz, made almost at the end of the seventeenth century, that the Pope and the Emperor of Germany be joint public arbitrators.

A few years later a more elaborate plan was advocated by the Abbé de Saint Pierre who proposed a general league of Christendom.

Later in the eighteenth century, Jeremy Bentham advocated a federation of the nations for the purposes of international justice, which should be administered by a common tribunal.

Towards the close of the eighteenth century, Immanuel Kant, in his famous essay "Touching Eternal Peace," advocated a congress of free nations to meet when necessary, to decide international disputes.

During the nineteenth century, there were many instances of the successful application of the principle of international arbitration to the solution of international difficulties which the resources of diplomacy failed to settle.

Probably the most notable triumph of the principle was that crystallized in the Treaty of Washington, 1871, between Great Britain and the United States. By this Treaty several disputes, some of long standing, and all causes of great irritation, were referred to different Boards of Arbitrators.

What were known as the Alabama claims were referred to a board of five arbitrators, one to be nominated by the President of the United States, one by Her Britannic Majesty, one by the King of Italy, one by the President of the Swiss Confederation, and the fifth by the Emperor of Brazil. The agreement of reference stipulated that the arbitrators should be bound by three rules, therein stated, as to the obligations of neutral Governments, and by such of the principles of International Law, not inconsistent with these three rules, as the Arbitrators should determine to be applicable to the case. The result was expressed in the "Geneva Award," so called because the arbitrators met at Geneva.

By this same Treaty, certain claims, other than Alabama claims,

were referred to three commissioners to be nominated, one by Great Britain, one by the United States, and the third by the King of Spain.

By this same treaty it was referred to three commissioners to be appointed, one by Great Britain, one by the United States, and one by the Emperor of Austria and King of Hungary, to determine the compensation to be paid for the use of Canadian fisheries by American citizens. This resulted in the Halifax award. The determination of the North-West boundary of the United States was left by the same treaty to the Emperor of Germany in terms which rendered a decision in favour of the United States a foregone conclusion.

In 1848, Lord Palmerston suggested an agreement between Great Britain and the United States not to begin hostilities in any case of difference between them, unless they should first have had recourse to the mediation or arbitration of some friendly power. For many years there was strong agitation in both Great Britain and the United States in favour of an Arbitration Treaty between the two countries. Resolutions were adopted both by the United States Congress and the British House of Commons. As a result the treaty known as the Anglo-American Arbitration Treaty, usually referred to as "The Pauncefote-Olney Treaty," was negotiated between the Governments of Great Britain and the United States of America. This Treaty was to remain in force for five years, and further, until the expiration of twelve months after either of the parties should have given notice to the other of its wish to terminate the treaty. By this treaty Great Britain and the United States agreed to submit to arbitration, in accordance with its provisions and subject to its remedies, questions in difference between them which they might fail to adjust by diplomatic negotiations. It provided for arbitration:—First, as to pecuniary claims, or groups of pecuniary claims, which did not in the aggregate exceed £100,000, and did not involve the determination of territorial claims; likewise for the determination of cases of pecuniary claims exceeding £100,000, provided that such matters in difference did not involve the determination of territorial claims. Controversies involving the determination of territorial claims were to be submitted to a tribunal composed of six members, three of whom should be judges of the Supreme Court of the United States, or Justices of the Circuit Courts, to be nominated by the President of the United States; and the other three to be Judges of the British Supreme Court of Judicature, or members of the Judicial Committee of the Privy Council. The award of a majority of not less than five to one was to be final; but in the case of an award made by less than this majority, the award was to be final, unless either party should, within three months after the award had been reported, protest that the same is erroneous. This treaty having failed to receive the necessary two-thirds majority in the Senate of the United States, did not become operative.

It may be disappointing to reflect that in pagan Greece, Argos and Lacedæmon could agree that if any differences should arise between them, they should have recourse to the arbitration of a neutral power, in accordance with the custom of their ancestors, and yet that at the end of the nineteenth century of the Christian era, the two most advanced nations could not conclude a similar agreement to continue for five years.

Yet notwithstanding it must be said that there has been an advance of the principles of international arbitration, a steady growth of public sentiment in favour of settling international disputes by the decision of an impartial Judicial Tribunal, instead of deciding them by the equity of the rifle and the justice of the sword. As evidence of this, reference may be made to the numerous instances of successful arbitration,—for example, the Behring Sea Arbitration.

Probably the most important advance yet made in the development of the principle of arbitration is found in the action of "The Peace Conference," at the Hague, in 1899. This conference was the outcome of an invitation contained in the rescript of the Emperor of all the Russias dated August 24th, 1898, stating that the maintenance of general peace and a possible reduction of the excessive armaments which weigh upon all nations, present themselves in the existing conditions of the whole world as the ideal towards which the endeavours of all Governments should be directed, and the Russian Government expressed the conviction that the time would be favourable for seeking, by means of international discussion, the most effectual means of insuring to all peoples the benefits of a real and durable peace. The object of the conference was stated to be, to converge in one powerful focus the efforts of all states which are sincerely seeking to make the great idea of universal peace triumph over the elements of trouble and discord, and to confirm their agreement by the solemn establishment of the principles of justice and right upon which repose the security of states and the welfare of peoples. This invitation was accepted by all the powers to whom it was addressed, *i.e.*, all the Governments having diplomatic representation at St. Petersburg, as well as Luxemburg, Montenegro and Siam. The delegates of the powers so represented met at the Hague on the 18th of May, 1899. Great Britain was represented at the conference by Lord Pauncefote, Sir Henry Howard, Vice-Admiral Sir A. Fisher, Major-General John Ardagh, R.A., and Lieutenant-Colonel Charles A. Court, R.A. The countries represented were Germany, the United States of America, Austria-Hungary, Belgium, China, Denmark, Spain, France, Great Britain and Ireland, Greece, Italy, Japan, Luxemburg, Mexico, Montenegro, the Netherlands, Persia, Portugal, Roumania, Russia, Servia, Siam, Sweden and Norway, Switzerland, Turkey, and Bulgaria.

The constitution of this now historical conference is extremely interesting. The work was done mainly by three committees; the first dealing with the question of limitation of armaments, the second with what is called the humanizing of war. In this paper we have only to do, however, with the work of the third committee which dealt with the subject of good offices, mediation and international commissions of enquiry, and arbitration. The deliberations of this third committee resulted in what was described as a convention for the peaceful adjustment of international differences. This convention recited that the high contracting parties were animated by a strong desire to concert for the maintenance of the general peace and that they were resolved to second by their best efforts the friendly settlement of international disputes. They also profess to recognize the solidarity which unites the members of the society of civilized nations, and the desire of extending the empire of law and of strengthening the appreciation of international justice. The conviction is recited that the permanent institution of a court of arbitration, accessible to all in the midst of independent powers, will contribute effectively to this result. The convention further recites the advantages attending the general and regular organization of arbitral procedure, and that they share the opinion of the Czar, that it is expedient to solemnly establish by an international agreement the principles of equity and right on which repose the security of states and the welfare of peoples.

The first article of this convention provides that, with a view to obviating as far as possible recourse to force in the relations between states, the signatory powers agree to use their best efforts to insure the pacific settlement of international differences. The second title (comprising articles II to VIII inclusive) deal with good offices and mediation. The third title (comprising articles IX to XIV inclusive) deals with international commissions of enquiry. The fourth title (articles XV to LVII) with international arbitration. Article XV states that international arbitration has for its object the determination of controversies between states by judges of their own choice upon the basis of respect for law. The effect of this provision plainly makes the submission to arbitration purely voluntary.

Article XVI recites that in questions of judicial character, and especially in questions regarding the interpretation or application of international treaties or conventions, arbitration is recognized by the signatory powers as the most efficacious, and at the same time the most equitable method of deciding controversies which have not been settled by diplomatic methods.

Article XVII provides that an agreement of arbitration may be made with reference to disputes already existing, or to those which may hereafter

arise. It may relate to every kind of controversy, or solely to controversies of a particular character.

Article XVIII provides that the agreement of arbitration implies the obligation to submit in good faith to the decision of the arbitral tribunal.

Little would be gained by a reference to arbitration which is subject to such a reservation as that said to have been suggested by the late President of the Transvaal Republic, who wanted arbitration, but said that if the arbitrators did not decide in his favour he would fight. It cannot, of course, be contended that every discussion of an arbitral tribunal is valid and binding. Heffter states the following six grounds of objection to an arbitrators' award:

1st. "If given without any sufficient agreement to refer beyond the terms of the agreement." (It was on this ground that the United States, in 1831, rejected the award of the King of the Netherlands as to the Canadian boundary, made pursuant to the Treaty of 1829.)

2nd. If given by arbitrators who turn out to be utterly incapable.

3rd. If the arbitrator or the other side has not acted in good faith.

4th. If the parties or one of them have not been understood.

5th. If the judgment relates to things not in dispute.

6th. If its terms are absolutely at variance with the rules of justice, and can not therefore form the subject of any agreement. (On this ground, the award of the Roman senate, on a reference to them of a dispute to certain lands between two towns, that the lands belonged to the Roman State, would be objectionable, but in that case the award was carried into effect.)

Article XIX provides that, independently of existing general or special treaties imposing the obligation to have recourse to arbitration on the part of any of the signatory powers, the powers reserve to themselves the right to conclude, either before the ratification of the present convention, or subsequent to that date, new agreements, general or special, with a view to extending the obligation to submit controversies to arbitration in all cases which they consider suitable for such submission. Of such treaties there are already many. Special reference need only be made to the one between Italy and Argentina, by which it was agreed to refer all disputes, without exception, to arbitration. In addition to these Arbitration Treaties, arbitration clauses have been introduced into numerous other treaties.

Article XX provides that, with the object of facilitating an immediate recourse to arbitration for international differences which could not be settled by diplomatic methods, the signatory powers undertake to organize a Permanent Court of Arbitration accessible at all times, and acting, unless

otherwise stipulated by the powers, in accordance with the rules of procedure included in the convention.

Article XXI provides that the Permanent Court shall have jurisdiction in all cases of arbitration, unless there shall be an agreement between the parties for the establishment of a special tribunal.

Article XXII provides for the establishment of an International Bureau at the Hague.

These sections determine, as far as the Hague Convention is concerned, the long controversy as to the advisability of having a Permanent Tribunal, or, in case of any particular controversy, of creating a Tribunal *ad hoc*. The late Lord Chief Justice Russell was a powerful advocate of the latter plan, one advantage of which is that in that way a tribunal specially qualified for the settlement of the particular dispute may be selected.

Article XXIII provides that each signatory power shall select not more than four persons of recognized competence in questions of international law, enjoying the highest moral reputation, and disposed to accept the duties of arbitrators. The persons thus selected shall be enrolled as members of the Court upon a list to be communicated by the Bureau to all the signatory powers. The members of the Court are appointed for a term of six years, but their appointment may be renewed.

Article XXIV provides that whenever the signatory powers wish to have recourse to the Permanent Court for the settlement of a difference which has arisen between them, the arbitrators selected to constitute the tribunal which shall have jurisdiction to determine such difference shall be chosen from the general list of members of the Court. Should such arbitral tribunal not be constituted by the special agreement of the parties it is to be formed by each party naming two arbitrators. Those together are required to choose an umpire. If the votes are equal, the choice of the umpire is to be entrusted to a third power, selected by the parties by common accord. If an agreement is not arrived at in this way, each party is to select a different power, and the choice of the umpire is to be made by the united action of the powers thus selected. The members of the court in the discharge of their duties, and outside of their own country, are entitled to enjoy diplomatic privileges and immunities. The court of arbitration is usually to sit at the Hague, and except in cases of necessity, the place of sitting is not to be changed by the court without the assent of the parties.

By Article XXVI, the International Bureau at the Hague is authorized to put its offices and its staff at the disposal of the signatory powers, for the purpose of the duties of any special tribunal of arbitration. The

jurisdiction of the permanent court may be extended under conditions prescribed by this rule to controversies existing between non-signatory powers, or between signatory powers and non-signatory powers, if the parties agree to submit to this jurisdiction. The signatory powers declare that they consider it their duty, in case a serious dispute threatens to break out between two or more of them, to remind these latter that the Permanent Court of Arbitration is open to them; that consequently they declare that the effect of reminding the parties in controversy of the provisions of this convention, and the advice given to them, in the higher interests of peace, to have recourse to the Permanent Court, can only be considered as an exercise of good offices.

Article XXVIII provides for a permanent Administrative Council, composed of the diplomatic representatives of the signatory powers accredited to the Hague, and of the Netherlands Minister of Foreign Affairs, who shall act as president. This Council is charged with the establishment and organization of the International Bureau, which remains under its direction and control. It is empowered to make its own by-laws, and all other necessary regulations, and to decide all questions of administration which may arise, with regard to the operations of the court. It has control over the officials and employees of the Bureau. All decisions are made by a majority of the votes. The expense of the Bureau is borne by the signatory powers, in the proportions established for the International Bureau of the International Postal Union.

Chapter 3 of this Title provides for a code of arbitral procedure, which is to be applicable unless the parties have agreed upon different regulations.

Article XXXI of this code provides that the powers who resort to arbitration shall sign a special act, which we should call a submission, in which the subject of the difference shall be precisely defined, as well as the extent of the powers of the arbitrators; and this is declared to imply an agreement by each party to submit in good faith to the award.

The only other portion of this code of arbitration procedure to which time will permit a reference, is Article XLVIII, providing that the Tribunal is authorized to determine its own jurisdiction by interpreting the agreement of arbitration or other treaties which may be quoted in point, and by the application of the principles of international law.

Russia did not invite the South American Republics to the Hague Conference, the United States and Mexico being the only American powers represented, unless Great Britain and the other European countries having possessions on this continent, can properly by virtue thereof be classed as American powers.

Subsequently however, there was held in Mexico what is known

as "The Pan-American Congress of 1901." This resulted in a Convention to which the United States and the Central and South American Republics were parties, providing for the compulsory reference to arbitration of all claims for pecuniary damages which may be presented by their respective citizens, and which, in accordance with international law, can be submitted through diplomatic channels, and can not amicably be adjusted through such channels, provided such claims exceed the sum of $10,000 in gold; and provided, further, that such claimants shall not have voluntarily served or aided subsequent to the ratification of the protocol containing this provision, the enemies of the government against which the claim is presented.

At this Congress the Hague Tribunal was recognized as worthy of confidence.

Such, then, is the present position of International Arbitration. How far has the world, or that part of the world which calls itself civilized, progressed towards the ideal so eloquently stated by Vattel long ago—in the following words:

"As the end of the law of nations is the happiness and perfection of the general society of mankind, it enjoins upon every nation the punctual observance of benevolence and good will, as well as of justice, towards its neighbours. This is equally the policy and the duty of nations. They ought to cultivate a free intercourse for commercial purposes, in order to supply each other's wants, and promote each other's prosperity.

The variety of climates and productions of the surface of the globe, and the facility of communications by means of rivers, lakes, and the ocean, invite to a liberal commerce, as agreeable to the law of nature and extremely conducive to national amity, industry and happiness."

One may not doubt that—

. . . . "through the ages one increasing purpose runs,
And the thoughts of men are widened with the process of the suns."

But the increase is often hardly perceptible and there is a great deal of widening yet to be done.

A very distinguished American recently declared that the principles which had guided the diplomacy of the United States were the Golden Rule and the Munroe Doctrine. The student of American history is puzzled as to whether the orator had in his mind the revised version of the Golden Rule, as given by David Harum, "Do unto the other feller the way he'd like to do unto you, an' do it fust," or the good old rule,

"That they should take who have the power
And they should keep who can."

When the Munroe Doctrine is nowadays spoken of, there is not necessarily any reference to the famous State Paper prepared and issued by President Munroe at the suggestion of Canning. That was a declaration fully justified by international law and by the special exigencies of the time. The present-day statements of the so-called Munroe Doctrine, involving as they do a claim on behalf of the United States to the hegemony of the whole American Continent, are quite a different matter. The Doctrine as now enunciated, and amounting to a claim of overlordship by the United States over the rest of the continent, has no basis in reason or justice, and is in direct conflict with the fundamental principle of international law which postulates the Territorial Sovereignty of Independent States. The United States, in adhering to the Hague Convention, reserves by a declaration all questions of the Munroe Doctrine. The plain meaning of this is, not that the other signatory powers accept the so-called Munroe Doctrine, but that the United States decline in advance to submit any question relating thereto to arbitration. The Doctrine as now propounded is based on might not on right. Those who would dispute any attempted application of the Doctrine must however bear in mind that might often prevails.

Another feature to be noted is, that in connection with arbitration negotiations, such controversies as affect "the vital interests or the national honour of contracting States," are almost invariably excepted. Vattel indeed excepts from disputes to which the method of settlement by arbitration would be suitable, such as concern the safety of states. Indeed nothing has yet been devised to supersede the rule laid down by Carlyle, that where there is a will to quarrel there is a way. Where, on the other hand, there is a will to avoid a quarrel, International Arbitration affords an honourable and equitable way to do so, and in that consists its main usefulness.

In the last analysis, the cause of peace depends on a gradual development of the sense of justice, of respect for the rights of others, and of reverence for law. Nevertheless, formal treaties of arbitration may well be advocated by those who in all nations are endeavouring (to use the eloquent language of M. Bourgeois, one of the French delegates to the Hague Convention) to bring the future of humanity under the majesty of the law.

ULTRAMICROSCOPIC ORGANISMS.

By J. J. MACKENZIE, B. A., M. B.

(Read 30th January, 1904.)

WITH the discovery of bacteria and the demonstration of their form and dimensions by the older bacteriologists, the question very early arose as to whether, with the recognition of these minute forms of life we had reached the limits of size of organized beings or whether there were not smaller organisms yet which we had not seen or could not see because of their minuteness. This question became the more pressing, the more we sought in vain for the organisms which caused such diseases as scarlet fever, measles, small pox, rabies and many other forms of infection; and the idea was frequently expressed that there must be forms of life smaller than the smallest known bacteria, so small in fact, that they probably were beyond the range of microscopic vision, and that on this account we have failed to find the parasites of these diseases. In regard to bacteria a striking fact may be noted in the remarkable uniformity of size of the various members of the group. They vary, it is true, enormously in the length of their cells or cell complexes, but in regard to the thickness of the cell or the diameter of globular forms, individual members of the group vary very slightly from an average of 1.0 micron to 1.5 microns. If we take one of the largest as an example, called on account of its size *bacillus megatherium*, we find that its width does not exceed 2.5 microns, whilst the smallest of the disease-producing forms, the bacillus which causes epidemic influenza, has a length of 1.2 microns and a width of 0.4 micron. Recently Erwin von Esmarch has described a putrefactive spirillum from water which is 1.3 microns long and 0.1-0.3 micron wide, the smallest of the bacteria which has ever been cultivated.

The possibility of demonstrating the existence of organisms which are too small to see with the strongest microscope would seem to be a difficult problem, and so it is, and we consequently cannot proceed to the demonstration by ordinary methods of bacteriological research. It has been necessary to adopt certain what might be called extraordinary methods to give evidence of their existence.

Fortunately for the success of the demonstration, those which have so far been discovered are all parasitic and consequently experiments can be made by animal inoculation and the presence of the hypothetical parasites demonstrated by the disease produced in the animal. In addition to this, however, we have in the laboratories, filters which can successfully

filter out the vast majority of known bacteria and which have been used regularly for this purpose for many years. These filters are all of the same type, in that they have pores so small that bacteria cannot be washed through them. The first to be manufactured consisted of an unglazed porcelain and was called the Pasteur-Chamberland filter, but there are now a number of different forms such as the Berkefeld which consists of compressed infusorial earth, and which are equally successfully. The impermeability of a Pasteur-Chamberland or a Berkefeld filter to bacteria is due to the fact that the minute passages or pores are not only small but tortuous and consequently the first organisms which pass on to the surface or into the mouths of the pores are caught and form a film which assists in rendering the filters even more effective. On the other hand it has been shown that many bacteria which cannot be driven through these filters by pressure can grow through their walls if given time and especially if they have the power of independent motion. The effectiveness of the filter is therefore due to the thickness of the walls and the tortuosity of the passages as well as to their minuteness.

An organism which could readily pass through such a filter would probably be of ultramicroscopic size and it has consequently been by a combination of the method of animal inoculation and filtration through such a filter that these organisms have been discovered.

Practically the first knowledge which we have of such minute living creatures resulted from the work of Lœffler and Frosch upon foot and mouth disease. These investigators undertook for the German Government a study of this disease which is a serious menace to the stock raising industry of various parts of the world and has for the human race the additional interest in that it is communicable to man.

In this disease, the characteristic feature is the presence of small vesicles or blebs upon the mucous membrane of the mouth and lips, and also about the hoofs of the forefeet. The eruption of vesicles is accompanied by more or less constitutional evidence of disease. The disease is exceedingly contagious, sweeping through a herd or from herd to herd with great rapidity. The vesicles on puncture yield a small amount of clear serous fluid and Lœffler and his colleague found that the contagion, whatever it was, was present in this serum. Microscopic examination of this fluid did not show anything which could be interpreted as a living organism although a minute quantity of it was sufficient to infect another animal. They therefore assumed that it was probably ultramicroscopic and endeavoured to see if it would pass through the pores of a Pasteur filter. Their results showed that the fluid is equally contagious after passing through the filter and they therefore concluded that it was smaller than any known organism.

The objection might have been raised to their interpretation of these results, that they were dealing with an excessively virulent soluble poison. To meet this objection they proceeded as follows. They found that the minimum infecting dose of the fluid from the vesicle was $\frac{1}{50000}$ c.c. They therefore, after diluting the lymph and passing it through the filter, inoculated animal 1 with $\frac{1}{50}$ c.c.; from the vesicles which developed upon this animal they collected the lymph, (about 3 c.c.) refiltered and inoculated a second animal with the same amount and so on through a series of six animals. Given the same amount of lymph collected in each case and the same dilution, we see that if it were only a poison the last animal would have received less than one two billionth of a c.c. of the original lymph. As it had been demonstrated that at least $\frac{1}{50000}$ was necessary for infection it is evident that reproduction must have taken place.

Another of these interesting organisms has been discovered by Nocard and Roux in the so-called contagious pleuro-pneumonia of cattle. The cause of this disease has been looked for by a number of investigators, but although numerous bacteria had been isolated, no one of them turned out upon further study to be the essential parasite. Nocard and Roux proceeded to investigate in a somewhat different manner. They demonstrated that the contagium was present in the serous effusion in the pleural cavity and in the lungs, but again could see nothing; they therefore tried this experiment. A sterilized collodion capsule, a little larger than a ten grain quinine capsule, was filled with sterilized bouillon, inoculated with a trace of the serous fluid and placed by operation in the peritoneal cavity of a rabbit. After a time it was removed and was found to have become milky or opalescent. In this opalescent fluid, it was shown by inoculation the organism was present in increased numbers and upon microscopic examination it was possible to see enormous numbers of minute dancing points, so small that no structure could be made out with the highest magnification. This virus would also pass through a Pasteur filter. Here we have a parasite just upon the borders of visibility.

Somewhat later, Beyerinck, a Dutch bacteriologist turned his attention to a curious disease of the tobacco plant, the so-called mosaic disease. This disease produces as its prominent symptoms the destruction of the chlorophyll of the leaves with the result that they become covered with yellow spots. It can be transmitted from leaf to leaf and from plant to plant by inoculation, the slightest trace of juice from the mosaic spot being capable of setting up the trouble in another plant.

Microscopic examination and culture methods were unsuccessful in revealing any bacterial organisms. The juice seemed absolutely clear and transparent, under the highest magnifications, although evidently very contagious. Beyerinck applied the filter test, and found the filtered

juice was equally virulent, and therefore concluded that here also we were dealing with an ultramicroscopic virus. He went, however, a step further, and showed what was still more wonderful—that the contagion was diffusible —that it would pass by diffusion through a layer of agar jelly, just as a salt in solution might pass, and he therefore announced that he had discovered a *contagium vivum fluidum* or, really, a soluble toxine, capable of reproduction.

Another animal disease, which for some years baffled investigators, was a type of chicken disease which prevails in northern Italy. It was for a long time confused with the co-called chicken cholera, which is due to a well known bacillus isolated by Pasteur. But further study sufficed to separate it from this disease, and numerous attempts were made, without success, to cultivate from injected birds a specific micro-organism.

Within the past year, the discovery has been made by Centanni and by two Austrian observers, independently, that in this particular disease, we have to do with a filterable virus. The blood of the animals contains the virus, and it is intensely virulent. A needle dipped in the infected blood, wiped off, and inserted beneath the skin of a healthy fowl, leads to its death in about thirty hours. This infected blood, when filtered through the densest of the Pasteur filters, does not show the slightest diminution in its virulence, and yet microscopic observation fails to reveal anything. Here again we have an example of a parasite of ultramicroscopic size.

There are several other diseases of domestic animals which, as a result of the filtration test, combined with the failure to demonstrate organisms by the high magnifications, are to be classed as due to ultramicroscopic organisms. One of the most important, recently discovered, is the African Horse Sickness, which McFadyen, in 1900, showed was due to a filterable virus. This virus, not only passes freely through the Pasteur filter, mark F, but even through the most compact form, mark B, which will hold back the virus of foot and mouth disease.

But undoubtedly the most important of all of these ultramicroscopic viruses, as far as man is concerned, is that of yellow fever.

It has this additional scientific interest that its demonstration has been of the most complete character, and wonderful practical results have flowed from the careful study of the conditions of transmission.

Our present complete knowledge of yellow fever we owe to the late Major Reed, of the U.S. Army Medical Service, one of the most eminent and reliable of American bacteriologists, and his associates—Carroll and Agramonte.

Yellow fever is a disease which has been studied with the greatest assiduity ever since the development of bacteriological methods, and

many have been the bacteria which have been isolated and made responsible for its ravages.

One of the earliest investigators was Stenberg, and his work is a really wonderful monument to the value of negative evidence. For although he isolated an immense variety of bacteria from yellow fever patients, he did not venture to connect any one of them specifically with the disease, and only risked calling attention to the more frequent occurrence of a certain form which he called *bacillus x*. It is not necessary to enumerate all the subsequent students of this subject, but some years ago Sanarelli, an Italian, trained at the Paris Pasteur Institute, went out to South America to study yellow fever, and came back with the announcement that he had at last discovered the cause in a form which he called *bacillus icterogenes*.

He was a tried and careful observer, and his work had the seal of the Pasteur Institute, and it was accepted by the majority of bacteriologists, so much so that we kept our cultures of *bacillus icterogenes* under lock and key for fear we should be responsible for the spread of the dreaded Yellow Jack.

However, doubts began to arise when Stenberg demonstrated that Sanarelli's bacillus was his *bacillus x*, and a little later Major Reed demonstrated that both the Sanarelli bacillus and *bacillus x* were simply varieties of the hog cholera bacillus.

With the discrediting of *bacillus icterogenes* the work had to begin all over again, and with the finish of the Spanish-American War Reed and his associates proceeded to Havana to study yellow fever in one of its endemic centres.

But they went with the accumulated results before them of a series of very important investigations into etiology and disease transmission, viz., with the results of Manson's and Ross's work in regard to the transmission of malaria by the mosquito. As early as 1881, however, a Havana physician, Dr. Carlos Finlay, had propounded the view that the mosquito was responsible for the transmission of yellow fever and it was natural that Reed and Carroll should turn their attention to the influence of the mosquito.

The results of the work of these investigators was to show that yellow fever could be communicated by blood taken from patients on the first or second day of the disease ; that it could be transmitted by a mosquito (*Stegomyia fasciata*) which had sucked the blood of a yellow fever patient, but only 12 or 25 days after the insect had had its meal of blood, that is, the parasite required to live a certain time in the mosquito. Further they showed conclusively that it could not be transmitted by fomites.

The practical outcome of this work has been that by excluding mos-

quitoes from the sick, *i.e.*, prevention of infection by mosquitoes, and exclusion of mosquitoes from the well, *i.e.*, prevention of infection by mosquitoes; it has been possible to rid Havana of yellow fever ; a practical result in disease prevention which has never been surpassed.

But the special interest which we have in this virus of yellow fever is in the fact that microscopic examination and culture methods failed to show organisms in the mosquitoes or in the blood during the first two days.

It was natural then that the filtration test should be applied and with positive results it was shown that the virus passed freely through a Berkefeld filter which was impermeable for bacteria.

It is quite possible that other human diseases may be found to be due to ultramicroscopic organisms but as far as some of the diseases of as yet unknown etiology are concerned, this is not likely. It seems that rabies for instance is not filterable. It is held back by the Pasteur filter*. Similarly vaccine virus will not pass through the filter. In regard to other diseases we do not know anything definite.

We may now ask ourselves what is the nature of these minute living particles? Are they simply smaller bacteria than we are accustomed to deal with, or are they a minute species of some type of animal parasite, or do they belong to a class of organism smaller and simpler than anything we have yet considered possible?

These are difficult questions to answer, but in regard to the first, we may perhaps be a little more positive.

I called attention at the beginning to the marked uniformity of size among the bacteria. That in itself is no proof that there may not be bacteria many times more minute than those we are accustomed to, but it is a presumption against that view. A more important reason however is in the fact that we have not yet met with an ultramicroscopic organism of a non-pathogenic character. They are all disease producers and if there were saprophytic organisms of this character they would certainly have been found, because it is the commonest experiment in a laboratory to pass fluid through a Pasteur filter in order to sterilize them without heat. I only know of one observer who purposely filtered a large number of different putrefying mixtures, both animal and vegetable, with the hope of finding a saprophytic ultramicroscopic organism. This was von Esmarch, and he failed entirely in a very large series of experiments, only finding a small spirillum which would pass fairly readily through the most permeable of the Pasteur filters.

* Recent work seems to show that the virus of rabies can be filtered through the most permeable of these filters.

It is probable that the virus of contagious pleuro-pneumonia does belong to the bacteria. It is, as I pointed out, just visible, and it is also cultivable outside the body. But this is the only one of this group, which I believe can be assigned to the bacteria. As we shall see, it is probably only slightly smaller than the width of half a wave length of the middle part of the spectrum, and consequently does not really differ much in size from the ordinary bacteria, and very slightly from such a minute form as the bacillus of influenza.

But in regard to the truly ultramicroscopic forms, such as the virus of foot and mouth disease, the fowl plague of northern Italy, the African horse sickness and yellow fever, we are in the greatest uncertainty as to position. It is true that in regard to Beyerinck's virus of the tobacco mosaic disease, he cuts the knot at once by calling it a contagium vivum fluidum, that is a living reproducing molecule or molecular complex so small and so simple that it is practically in solution in the fluids in which it is living and multiplying. There is nothing, *a priori*, to be urged against this view, but if such is the nature of these viruses, then we have to do with a new series of chemical compounds, with which we have as yet had no experience.

The nearest approach to a condition of matter comparable to such a living molecule is in the enzymes or unorganized ferments in the animal and plant body or the so-called catalytic agents, such as colloidal platinum. But these although active in most minute quantities, yet are definitely used up and cannot reproduce themselves.

There is really no argument to offer against this view except that we naturally are loath to accept the existence of such a substance until we can more definitely prove it. If this should be the explanation, however, then we would be getting much closer to the hypothetical first form of life upon the earth in that the distance between a living reproducing molecule or molecular complex and a molecule of dead organic matter must be very short.

The conditions which govern the destruction of these ultramicroscopic parasites have been studied, viz., the thermal death point, and the effect of disinfectants, and it is found that they do not differ materially in susceptibility from the higher and larger bacteria. For instance, moist heat of 55° C. for ten minutes destroys the virus of yellow fever, but the spirillum of Asiatic cholera is destroyed by 52° C. for ten minutes. Solutions of fluid disinfectants such as carbolic acid and mercuric chloride act in the same way upon them as upon bacteria, but in this they resemble also the enzymes and even the inorganic catalysers, as Bredig has shown.

There is only one fact which it seems to me rather militates against

this hypothesis and that is the one discovered by Reed and Carroll in regard to the virus of yellow fever.

They found that the mosquito which had become infected with the virus by feeding upon the yellow fever patient was not capable of transmitting the disease until at least twelve days had elapsed, and that then the incubation period in the infected person was five days. They also showed that 1.5 c.c. of the blood serum of a yellow fever patient withdrawn during the first two days of the disease and injected into a second person produced the fever in about forty-eight hours. Now it may be argued that the long sojourn in the body of the mosquito was necessary for a sufficient multiplication of the virus to produce an effective infection or that that time was necessary for the passage through the stomach to the poison glands, but it was found that the bite of the infected mosquito was harmless after eight or ten days, but harmful two or three days later, and we can hardly think that the difficulties of transit alone were sufficient to account for twelve days in travelling from the stomach to the poison glands. The phenomenon resembles much more that which appears in the transmission of malaria by the mosquito. Here the length of time which elapses is due to the parasite undergoing a necessary cycle of its existence in the body of the insect which results in the formation of minute sickle-shaped spores which then travel to the poison gland and are injected into the next person bitten.

If the twelve days which the yellow fever virus passes in the body of the *stegomyia* is required for the completion of say a sexual phase of existence then we would have to place it in the animal kingdom as an ultramicroscopic form related to the malarial parasites.

It will be seen, however, that a great deal more light must be thrown upon the subject before we can definitely place these invisible parasites in the scale of organized being, and the difficulties in the way are very great, first because of their minute size, second because as yet we do not know how to cultivate them, and thirdly because they are all parasites and consequently can only be studied in the living organism.

In regard to their minute size the question may be asked, must they be definitely placed for all time outside the range of microscopic vision or may our optical equipment yet develop to such an extent that we may demonstrate their organism and even smaller particles?

The theoretical limit of the power of the microscope to demonstrate structure is about 0.25 micron. *i.e.*, one half a wave length of the middle part of the spectrum. Below this magnitude minute particles will no longer show structure but will appear as diffraction discs. The smallest visible particle with the highest power of the microscope, structure being

neglected, is 0.05 so that our organism of contagious pleuro-pneumonia must be in size somewhere between 0.05 micron and 0.25 micron ; all the others must be under 0.05 micron. With ordinary methods they must always remain invisible, but about a year ago Siedentopf and Zsigmondy with the assistance of the Zeiss firm constructed an optical device which may lead us some distance in determining the approximate size of these parasites although it will never reveal to us anything of their structure. These investigators wished to study the condition of colloidal gold in the so-called gold ruby glasses ; the point to be determined being whether the gold was distributed as discrete particles or continuously through the glass. They attacked the question in the same manner as Tyndall many years ago attacked the question of the presence of fine dust particles in the atmosphere, viz., by the use of a fine pencil of sunlight.

By means of a heliostat, a spectroscopic slit aperture and a series of condensing lenses, a very fine slit of light was thrown into the glass at right angles to the line of vision. The plane of light was observed by means of a very high power microscope and when this was sharply focussed the light plane appeared as a dark ground filled with enormous numbers of brilliant particles. Each particle showed no structure, simply a diffraction disc due to the light being turned and thrown into the tube of the microscope, but nevertheless counts could be made and the size of the particles could be estimated.

The unit of measurement which they take is that used by the physicist and chemist, viz., the millimicron, written $m\mu$ $\frac{1}{1000000}$ mm, or $\frac{1}{1000}$ micron, and they found the size of the particles in the following manner. It can be demonstrated that the diffraction disc from particles smaller than .006 microns ($\frac{6}{1000000}$ mm) would be too small to see, consequently the size must vary between .25 micron and .006 micron. The number in a given cubic area of glass was counted, the amount of gold estimated chemically, and from these data and the specific gravity of gold the probable size calculated. By this means the smallest particles seen were estimated to be about .006 micron, whilst the average size was about .05 micron.

Now if we remember for a moment the estimated size of a molecule, varying from say 0.5 millimicron for the largest, or according to other authors 2 millimicrons for a molecule of albumen, down to .05 millimicron, we see that the smallest particles that this method can reveal are still some distance from molecular size.

But if the method were applied to our ultramicroscopic particles it might be possible to estimate how closely they approach the size of a molecule.

Recently Raehlmann, in the *Muenchener Medicinische Wochenschaft,* has applied the method to the study of coloured solutions and to solutions of albumen. In the albumen solutions he was able to see very minute particles, which disappeared when the solution was heated to the coagulation point. In glycogen solutions, when sufficiently dilute, particles could also be seen as well as in glucose and milk sugar solutions ; peptone solutions showed an exceedingly faint diffraction cone, but individual particles could not be seen.

With a glycogen solution of proper concentration this interesting experiment was performed. A drop of diastase was added to the fluid, and immediately the cone of light in the microscope disappeared, and in their place a larger and more scattered disc could be seen, which gave, according to Raehlmann, the same picture as that of dextrine or glucose. He thinks that in the glycogen what was seen was a special type of molecular complex, determined probably by the form of the simple molecule, and that by the addition of the diastase he was able to watch its passage into the isomeric sugar.

SCIENCE AND ENGLISH LAW.

PRESIDENT'S INAUGURAL ADDRESS.

BY GEORGE KENNEDY, M.A., LL.D., K.C.

(Read 12th November, 1904).

My first duty is to thank the members of the Canadian Institute for the honour they have seen fit to confer upon me in electing me to the high office of President. I am painfully conscious of the fact that I have small claim to an office that for fifty-five years has been filled by a succession of men eminent in various branches of science, in literature, and in jurisprudence, and can only attribute to the good will of my associates that I now find myself in this conspicuous position. I am happy to know, however, that the position of the Canadian Institute is so secure and so well-established that the deficiencies in its president can in no way affect its reputation among the learned societies of the world. Five years ago we celebrated its jubilee and were then able to congratulate ourselves on the results of fifty years' efforts in the pursuit of Science in nearly all its departments. And these last five years have very materially added to our prosperity. Our meetings have been better attended than they ever were before; the character and quality of the papers read have been well sustained; and the additions to human knowledge as the reward of original research by our members have been neither few nor unimportant. Our publications now amount to thirty-four volumes, and in return for our publications we receive those of all the leading scientific bodies of all lands. Our library is now the largest and most complete scientific library in the Dominion, and is being constantly added to by reason of our very large exchange list. You will have noticed by our minutes that since our meeting in May we have received no less than 1,293 exchanges from all parts of the world, indicating the rapidity with which our library grows. The value of all this literature to scientific students is incalculable. And to be of service to those whom it can most benefit, it should be conveniently located for them. It can hardly be said that our present location is well suited for that purpose. However well adapted for our purposes this building is, and however well situated it may have been when built, yet the business growth of our city and the advance of manufacturing establishments in all directions all round us, are such as to render necessary our removal to some more suitable locality at an early date. This subject is at present engaging the earnest attention of the Council, and we have reason to hope that we may be successful in finding proper accommodation in some

more desirable locality. Many of our most valued members are connected with the University, and it would certainly be advantageous that our library could be with convenience consulted by them. And it would suit the members generally better that our place of meeting should be further up town. And yet it is by no means desirable that the Institute should become a mere adjunct to the University. We have a mission of our own distinctly different from that of the University, and must preserve our own individuality. At the same time, a quasi-alliance will be of benefit to both institutions. I do not mean any definite formal agreement, but only such alliance as contiguity of place may afford for the promotion of those studies that are common to both.

The Canadian Institute was at first designed as an association of engineers, surveyors, and architects, but it has since broadened out, and now we put no limits to the objects of study. All science is within our purview. We aim at occupying in Canada a place similar to that of The British Association for the advancement of science in Great Britain. Indeed our practice is even broader than that of the British Association, for an examination of the titles of papers read at our meetings and published in our Transactions will discover numerous papers on literature, classical and modern, on history, on the fine arts, none of which are ever touched by the British Association. It was here that were first read those learned and ingenious papers on Roman Epigraphy by Dr. McCaul, which were afterwards collected and published as "Britanno-Roman Inscriptions." Here also were read those delightful sketches by Dr. Scadding, which developed into his book on "Toronto of Old." Many others might be mentioned. We have even had occasional papers dealing with some branches of English Law, which many persons may think has very little relation to Science. Those who have suffered in pocket or otherwise in consequence of the technicalities of pleading or the eccentricities of judges and juries may be pardoned for agreeing with the declaration of Mr. Bumble that "the law is a ass, a idiot;" and it would be hard to convince them that the Law is the perfection of reason, as it has been asserted to be. It makes a great difference from what standpoint one views the Law. To an outsider contemplating the vast mass of the customary or common law of England, of the so-called equity principles that have been established through the instrumentality of the Court of Chancery, of the statutes enacted in the course of hundreds of years, of the judge-made laws embodied in the countless volumes of Reports of judicial decisions, it may well seem that the English law is a hopeless jumble of confusion. But so is external nature. To the superficial gaze, the world is all confusion. The earth, the air, the sea, the forests, the rocks, animals, plants, sun, moon, and stars, to the untutored savage appear to be ruled only by caprice. He sees no order in the universe; the phenomena of Nature are but the acts of some malignant Moloch whose

dominion inspires naught but fear. Men imagine wars of gods and giants, and people the heavens with beings endowed in an exaggerated form with the same attributes themselves possess, and in this way account for what they see around them. Out of this groping after truth Science has grown; Chaos has been reduced to order; Nature girded with a beauty and grandeur inconceivable to our ancestors; the forces once deemed the sport of malignant demons have been chained to the service of man and made his docile slaves. These beneficent results have been accomplished in the slow progress of the ages by the persevering labours of men of science. How is it with English law? I fear the answer must be far from satisfactory. But before going farther, it may be well to consider what is meant by "law," and we shall find that its meaning is not so certain as might be thought. When we speak of the law of gravitation, we mean something totally different from the law which hangs a criminal for murder; the law of the conservation of energy has no analogy to the law which enables a landlord to distrain on the goods of his tenant for rent due on a lease; the law which determines the equation to the catenary has no conceivable relation to the law which established the rule in Shelley's case. In the former of these instances it is manifest that we mean by "law" a theoretical principle deduced from particular facts applicable to a defined group or class of phenomena and expressed by the statement that a particular phenomenon always occurs if certain conditions be present, or, as Johnson has it, an established and constant mode or process, a fixed correspondence of cause and effect; in the latter instances we mean by "law" a rule, whether proceeding from formal enactment or from custom, which a particular state or community recognizes as binding on its members or subjects, and collectively "the law" is the whole body of such rules.

Science, which is only another name for knowledge formulated or systematized, has been successful in reducing by the Baconian method of induction, the first named laws to definite systems; but it is far otherwise with the latter, so far at least as English law is concerned. Blackstone made a heroic attempt to compress the whole body of English law, as it existed in his time, within the compass of four portly volumes; and subsequent writers have in innumerable text-books summa ized the laws applicable to specific branches or divisions of the law; but these books, admirable as many, if not most of them are, are commentaries on the laws, and not the laws themselves. Philosophical jurists like Bentham and Austin, have theorized on codification, but the enormous difficulties in the way of reducing to system the crude mass of unwritten and judge-made law and merging it in the equally crude mass of statute law, combined with the innate conservatism that is so strong a factor in English character, has hitherto prevented any substantial progress. To codify the whole English law would require a long time and the labours of many minds. Hic labor, hoc opus est. But

it is not impossible. The Judicature Act revolutionized pleading and practice, abolished the irrational distinction between Common Law and Equity, did away with many technicalities that in the name of law were a travesty of justice, and introduced new methods founded on common sense, which have immensely simplified the work of the lawyer. We in the Province of Ontario have set the example of periodical revision and consolidation of the public statutes, and this is a very considerable step on the way to complete consolidation of the law. The Criminal Code is a splendid example of codification of one branch of the law; the laws relating to bills and notes have been systematized, and no reason appears why the whole mercantile law should not be similarly dealt with.

If this process of piecemeal operation were carried on, gradually all branches of the statute law would be brought within reasonable bounds. This being done, an attack would then have to be made on that multitudinous accumulation, which Austin called "judiciary law," contained in the tens of thousands of decisions given in the Reports. This might seem a hopeless task, but after all, the cases which introduce any new principle or rule, or euphemistically declare that to be law which was not known to be law before, are comparatively few, and have been collected and are known as "Leading Cases." Then we have the Digests, giving in brief the substance of the decisions on special subjects in alphabetical order. There is nothing to prevent these from being subjected to logical classification, and the resulting principles or rules succinctly stated and put in their proper place in the system. Thus having consolidated the statutes, and reduced to logical order the judicial pronouncements of the reports, the standard text-books could be consulted for verification; and the common or customary law, the statute law, and the judiciary law, woven into a complete, compact, rational system. An Act of Parliament would bring it into force, and from that day the student would not be appalled by the Serbonian bog which he now has to wade through in order to attain any knowledge of law; the practitioner would find his work made comparatively simple; counsel would give opinions with far more certainty than now; and the general public would no longer wax sarcastic over "the glorious uncertainty of the law."

I may seem to some to be too optimistic in these prognostications. I am aware that many objections that appear formidable have been made to any attempt to codify English law. Lawyers know them very well, and those who are not lawyers and may be curious in the matter will find them fairly stated and fully dealt with in Austin's thirty-ninth lecture. It will be sufficient for my present purpose to notice only two of these objections. It is objected that previous codes have been illogical, incomplete, imperfect, and unsatisfactory. Granted that some of them have been so, and even if we

admit that no one of them is perfect, surely that is no reason why the persevering skill of competent men should not be able to devise a scheme or construct a code more approximately perfect than any heretofore made. The very existence of defects that are acknowledged should lead to the ascertainment of the proper remedies, and their due application. One might as well say that because Savary's and Newcomen's steam-engines were imperfect, James Watt should not have attempted to improve on them. A similar argument would leave us still struggling with the errors of the Julian calendar, or the crudities of the Ptolemaic system of astronomy, and would sustain the position of our good friends who hold the flat earth theory. The material for an English code undoubtedly exists, and it is absurd to say that it cannot be drawn forth and hewn into shape that will conform to scientific principles. Further, it is not to be supposed that a code is to be as unchangeable as the laws of the Medes and Persians; the same power that enacts a code can incorporate amendments to correct defects that experience may discover.

And this leads to the other objection that I have alluded to. It is said that one of the beauties of English law is its flexibility and elasticity, and that this admirable characteristic would be destroyed by the rigidity of a code. English law certainly has flexibility and elasticity, but there is another quality that it has which is not so worthy of approbation, namely, uncertainty. Every lawyer knows how difficult it is to pronounce a decided opinion on points of law that are constantly arising in practice; the judges are every day differing in their judgments; one judge will rule one way on a certain state of facts and with certain precedents which he considers authoritative; another judge on the same bench with the same facts and the same authorities will rule another way; the judgment of one Court will be reversed by a Court of Appeal composed of judges in no way superior in knowledge or skill to those whose decisions they reverse; it is seldom a matter of certainty as to how a Court of final appeal will rule in any given case. Judges have been known to express regret that they were forced to rule in a certain way, considering themselves bound by the authority of precedents, the correctness of which they questioned. Other judges would in such a case disregard the precedents and rule according to their independent view. The source of this uncertainty lies in the fact, supposed to be a fact at least, that the law governing the particular case is hidden away somewhere in the reports, and has to be dug out from cases more or less nearly parallel to the one in hand, and construed, and if necessary, re-moulded to suit circumstances. I do not say that all this uncertainty would be obviated by the existence of a code, but I am safe in saying that it would be very much reduced, and at the same time the flexibility and elasticity of the law would be in no wise affected. For what is this flexibility and elasticity? Is it not simply the application to new conditions

of principles already established, the development by logical inference of rules laid down under certain circumstances and their adaptation to other circumstances as they arise, the evolution on a scientific basis of legal relations as modified by the ever-changing exigencies of society? How could such evolution be hindered by a code? Would it not rather be facilitated, if the rules of law were clearly and succinctly stated, so as to be easily referred to, rather than to be laboriously sought for in the constantly increasing volumes of law reports? The ideal code would render unnecessary any reference to the reports of cases determined prior to the date of its coming into force, but of course, law reporting would not be done away with. Periodically the results of judicial decisions, as well as of statutory enactments, would have to be incorporated in the code, and a new start made; for finality in legislation, whether judiciary or statutory, is impossible. Nature is so multifarious that we cannot imagine a time when science will have unravelled all its secrets; no more can we imagine a time when human nature will have reached such a development that legal progress will be unnecessary. No code can ever be perfect, but we may hope that a scientific codification of English law will sooner or later be an accomplished fact. When accomplished, it will be one of the greatest achievements of the human intellect.

There are many irregularities and imperfections in English law which an honest application of the principles of science will to a very great extent, if not wholly, remedy. In no direction will this be more marked than in the fixing of the punishments for crimes. It will be remembered that Blackstone, after giving his definition of a law as a rule of civil conduct prescribed by the supreme power in a state commanding what is right and prohibiting what is wrong, and analysing the various parts of this definition, goes on to speak of the sanction or vindicatory branch of the law, whereby it is signified what evil or penalty shall be incurred by such as commit any public wrongs, and transgress or neglect their duty. The law does not reward the law-abiding citizen; it only punishes the law-breaker. The object of punishment is frequently stated to be the reformation of the offender, but although that may very properly be one object of punishment, I think the prime object of punishment is the protection of society. The forgetting of this is the origin of much of the mawkish sentimentality of some good people in reference to this subject. The man who commits crime proclaims himself an enemy to society, and the safety of society demands that he should be withdrawn from society permanently, or at least until he shows by his conduct plainly and unmistakably that he has reformed and may safely be discharged from prison. The law acts on this principle when it prescribes capital punishment for the murderer, or perpetual imprisonment; but in the elaborate series of punishments prescribed for lesser crimes, the principle is lost sight of, and vengeance on the criminal seems

the only object aimed at. Of what use is it to imprison the burglar or the forger for five, or ten, or fifteen years, if at the end of the time he is let loose to prey upon society again? Again, the law in most cases gives a large discretion to the judge in fixing the penalty, and hence arises inequality which is frequently startling. A good-natured judge will let the prisoner off with a light punishment, whilst a judge of sterner character will for the very same crime impose the extreme penalty allowed. The remedy for this is what has come to be termed "the indeterminate sentence," which as well as being in the interest of society will be a great relief to the judges and possibly also to juries. Analogy from natural science will help us here. If a man accidentally cuts his finger, he ties it up with a piece of cotton, rendering the use of it impossible, and keeps it so tied up until the wound is healed. But if he takes the bandage off too soon, and attempts to use the finger before it is properly healed, he opens the wound possibly in a worse condition than at first, and is obliged to repeat the operation and wait longer for a cure than if he had had more patience in the first instance. So it is with the criminal. If upon trial and conviction he is condemned to a short term of imprisonment, he serves his term and is discharged, in ninety-nine cases out of 100, worse than when he began; he renews his war upon society, which is obliged to go again through the whole course of trial, conviction, and sentence, and the criminal sinks deeper and deeper in degradation and sin. A philanthropist in an address recently delivered in this city is reported to have advocated the letting off of first offenders. That seems to me to be dangerous doctrine. It is not in accordance with natural law, which invariably and inevitably vindicates itself against every violation of its behests. If this is the case in the material world, it is equally so in the moral and spiritual world. If the criminal escapes punishment, society is punished in his stead and the law is vindicated, but at what cost? Obsta principiis. Check the evil at the very beginning. That is the salvation of society. Will it be objected that this is Draconian severity? I answer that it is more merciful to restrain the criminal until he reforms, than to leave him to his own devices, which will certainly lead him astray. But look at the cost, some one may say. I venture to affirm that it will be cheaper to keep all the criminals behind bars than to maintain an army of policemen and other court officials, whose main reason for existence is the freedom allowed to the criminal class, leaving out of consideration altogether the losses of individual citizens by reason of their depredations. It is an obligation upon society to pay for its own protection.

There is another reform which the application of the teachings of science to law will effect, which is worthy of our attention, I mean the treatment of those who are not criminal but only diseased. Time was when insanity was treated as a crime, when lunatics were loaded with chains and shackled in dark dungeons, their scanty food thrown to them as to wild

beasts, no effort made to keep wholesome the wretched cells in which they were left to rot in filth and misery. This reproach to our civilization is not even yet wholly removed, for our law empowers magistrates to commit persons of unsound mind to jail. Is it irony, or what is it, that here the indeterminate sentence prevails? Grand juries are constantly protesting against this crying shame, which ought to be put an end to speedily. The jail is no place for these unfortunates. But there is another class whose case deserves consideration, I mean the victims of drink. Drunkards are not criminals, they are diseased. It may be a crime to give the drunkard drink, but it is no crime in him to drink. He cannot help it. He has no more power to resist the craving of diseased appetite than has a log cast into the rapids above Niagara power to resist plunging over the Falls. How absurd is it to inflict upon these poor creatures the penalty of a dollar and costs or thirty days in jail! Day after day, week after week, month after month, men, and women too, are hauled before the police magistrate, and committed and re-committed to jail, against whom the only charge is getting drunk. It is impossible to reform these people in this way. They are subjects for the medical man, not for the judge, or even for the preacher. Cure their bodies first, and then you may talk morals and religion to them with some hope of success. We have insane hospitals, smallpox hospitals. fever hospitals, tuberculosis hospitals; we want also inebriate hospitals, in which the victims of drink shall be treated as patients, not as criminals, and the resources of medical science drawn upon for their relief and ultimate restoration to health.

Scientific methods again would enforce a proper classification of prisoners in our jails, so that the young and comparatively inexperienced in crime should not be thrown into the company of hardened offenders, by whom they are inevitably made worse. It is true that in some of our prisons attempts are made in this direction with more or less success; but there is a plentiful lack of uniformity in this matter, due to the fact that the management of these institutions is under the local County Councils, which bodies are not always distinguished for intelligent action. It is not enough that the jails be subject to periodical inspection. No amount of inspection will convert a building that is architecturally defective and without the means for classifying the inmates, into a proper building; inspection will not atone for municipal stinginess or wrong-headedness. The central authority should control all prisons; build them on a general plan as nearly uniform as possible, with every facility for segregation; and their government should be entrusted only to persons thoroughly trained and instructed for the performance of the very important duties expected of them. Would it indeed be going too far to say that there should be a school for training jailers and guards, and that all appointments to such positions should be made only from those so trained instead of by the present hap-hazard method?

There is no branch of English law that offers more difficulties to the student than real property law, with its mysteries of fines and recoveries, of estates in fee simple and fee tail, in possession or expectancy, of shifting and springing uses, of contingent remainders, of trusts, of tenancies by the curtesy and by entireties, of bargain and sale, of lease and release, and all the other curious relics of the feudal system. Happily most of these sources of perplexity have been removed by legislation that may be called recent, but a great deal has yet to be done to make the law of real property conform to true scientific method. Very early in the history of our Province a system of registration of deeds was adopted which greatly assisted the investigation of titles in tracing the chain from the original grant from the Crown; and more recently the Act for Quieting Titles was passed, under which a certificate from the Court is substituted for the Crown patent as a starting point. More recently still the Land Titles Act was passed, the aim of which is to assimilate the transfer of land to that of personal property. Unquestionably it is a move in the right direction and will no doubt be followed by improvements that time and experience will shew to be advisable.

Turning to another aspect of the relation between Science and Law, we may note the necessity to the successful practitioner of a knowledge of many branches of science that formerly were deemed of little account. The time has passed when the ability to stumble through a little Latin and geometry is sufficient preparation for beginning the study of the law. The man who would be a successful lawyer in this age of intense, all-absorbing practicality must know something of almost every department of human knowledge. A dispute as to boundaries between farms may involve an acquaintance with surveying and those branches of mathematics upon which surveying depends; questions as to patents require a knowledge of mechanics and other departments of natural philosophy; questions as to water-powers demand a knowledge of hydraulics and hydrostatics; to manage a case of killing by poison, it is necessary to understand the chemistry of poisons and their effect on the human frame, thus bringing in the study of physiology; a recent case which is now distracting all Scotland shews that the lawyer must be able to discuss even hair-splitting points of dogmatic theology; and as for politics, the great numerical preponderance of lawyers in our legislative bodies, shews the intimate connection between law and government. The lawyer should be an all-round man, totus, teres, atque rotundus, able to deal with almost any question that may arise in any contingency.

I have alluded to the intense, all-absorbing practicability of the age. Herein lies one of the grave dangers of modern life. The passion for money that is so prevalent in these days threatens to smother the finer feelings and sensibilities; it has invaded the domain of the education of our youth, and

the demand is made that only those subjects should be taught in our schools and colleges that bear directly on the methods of acquiring wealth.

> Rem facias, rem;
> Si possis, recte; si non, quocunque modo rem.
> Scotticè—"Siller, get siller; honestly, if ye can;
> but if no, ony way, get siller."

This is a poor motive, and is by no means a legitimate corollary from the demand for scientific study. In order worthily to cultivate any or all branches of science, the intellect must be trained, and long experience has demonstrated that nothing sharpens the faculties more than the study of the ancient languages of Greece and Rome and the splendid literature embalmed in them. The student who has spent a few years in earnest acquisition of classical learning, is much better fitted for the close observation of facts required in scientific research than he who is altogether devoid of that knowledge. I deprecate, therefore, the tendency to abandon the humanities, and would hope that our education law may not be tinkered overmuch by the fancy for so-called practical objects. Our education law must be adapted to the progressive spirit of the age, but what is good in the old way must not be recklessly cast aside.

I have thus indicated very cursorily a few of the directions in which our body of law may be improved by adopting the methods of modern science. The legislator who will inaugurate the work of codification of our law and the reforms that have been suggested, will deserve well of his country, and I would encourage those who may engage in the work by quoting the aphorism of Cato, "Vigilando, agendo, bene consulendo, omnia prospera cedunt."

THE PRINCIPLES OF INSURANCE, WITH ESPECIAL REFERENCE TO SICK BENEFIT PROVISION.

BY ARTHUR HARVEY, F.R.S.C.

(Read 26th November, 1904).

WHILE gathering up the statistics of the various provinces of British North America, in view of their impending confederation, into a collection subsequently published with the permission of government under the title of "The Year Book of Canada," no feature made more impression on me than the astonishing persistence of averages. Even in such details as accidental deaths, somewhat similar numbers were shown to be killed each year by trees falling on them, poisoned by toxic berries, or the like events, which it seemed might show abnormal figures. This very day I read in the morning papers the following news telegram :—Chicago, November 25, "Thirteen deaths have resulted from football this season. The casualty list is the same as last year." In speaking of this with Sir Alexander, then the Hon. Mr. Galt, Minister of Finance, my chief, he added that even errors of judgment tended to balance themselves, and that in making estimates of probable public revenue and expenditure he had several times been astray in particulars, but was usually correct as to totals. In estimating probable returns from new or changed taxes, such as revenue from law-stamps and stamps upon notes of hand, or such things as the results to trade of abolishing interprovincial tariffs, similar experiences afterwards befel me too.

It is upon this principle of the persistence of averages that insurance is based, whether fire, life, marine or miscellaneous.

As on leaving the government service I took charge of the Provincial Insurance Company of Canada, fire and marine, which soon involved the care of a small life insurance company as well, I can speak of these branches from experience as well as theory.

Of the various kinds of insurance, that which deals with the risk of fire, is, I think, the most difficult to regulate aright. The circumstances which cause loss are so constantly and rapidly changing that a rate of premium which is adequate in one decade may be much astray in the next. I once directed the classification of more than fifty thousand risks and the losses thereunder, covering a number of years, and found the work was only useful in shewing what hazards were improving and what becoming more

dangerous. The inequalities in different parts of the country on what seemed similar risks were a remarkable feature of the summary, and these alone proved that the rate indicated was not a reliable index of what a general tariff should be, or, rather, that a uniform tariff cannot justly be adapted. In parts where coal was being rapidly substituted for wood, as fuel, the fire hazard was decreasing, while the introduction of burning fluids and mineral oils for lighting was attended by a considerable increase of danger, through explosions. It was once asserted that electric lighting would do away with risk from artificial lighting, but it was soon made apparent that the danger from defects in wiring, original or developed from use and accidents, is very real. Losses in all kinds of manufacturing business seemed to increase both on the crest of good times and in the worst of bad ones, quite irrespectively of the moral hazard, which probably follows a different rule. The elevators every large city building must now have are a very pregnant danger, facilitating both the origin and the rapid spread of fires. The government returns show that there has been for several years past a steady increase in the rate of premium charged, the figures being

1899.....$1.25	1900.....$1.25	1901.....$1.42
1902.....$1.47	1903.....$1.50	

This may result from combination among the insuring companies. I am, however, inclined to think that there has been an actual increase of hazard in the business quarters of rising towns and cities, due to defective construction, flimsiness of material, and especially the increase in the size of buildings and stocks. This implies more hands, often organized into departments, which are almost so many separate tenancies. There are now fewer lots vacant to break the spread of a fire. And in a large establishment, once a fire is master, the heat is greater than in a small one, and the task of checking the conflagration harder. The whole business, in this country of such changing circumstances, has often reminded me of a game of blind-man's buff, in which the chief actor has only slight indications to guide his uncertain steps. Once indeed I classified a company's declined risks for several years, and while there was not the same certainty that all the losses were reported and correctly stated, the extra percentage did not seem alarming, there would have been a profit in carrying the risks, and on reasoning the matter out with the assistant secretary of my company I reached the conclusion that the local agents should be little interfered with except in cases of a glaring tariff error, or when the black list shewed previous incendiarism unexplained, or when mercantile agencies indicated bad business habits. Some fire underwriters have been known to make public brag that they at least can adjust premiums to hazards in the certainty of gain, and I have known a few who have had a great run of luck, but I have never thought

it useful to question their gifts of foresight nor have I ever known a case in which that good fortune has been really lasting.

Insuring companies naturally claim that the rates of premium current are too low, but the government tables of statistics scarcely bear out this contention. The summary for 1903, page xvii, which refers to Canadian companies alone, does indeed show that on the average of the four years, 1900-03, they spent 63 per cent. of their premiums in paying losses and 33 per cent. for expenses, leaving no margin for profit, still less for what may be called a conflagration reserve. If we wish for a longer average, we must include all companies doing business in Canada, for at the beginning of the period 1875-1903, the proportion of the total due to Canadian companies was small. The official statistics show that during that period, which included one conflagration, the companies paid 68 per cent. for losses and 33 per cent. for expenses, so that they had practically neither a profit nor a loss, for the interest on premiums received would equal the apparent deficiency of one per cent. But what any business man will at once single out for remark is the large expense account. To reduce this should be the companies' aim, rather than to increase rates, and perhaps, now that mergers are in the air, they may be applied to fire insurance. Without a radical change in methods there can be but a small chance for a saving in this item. I did once reduce the expense account of my company below 30 per cent. but found the volume of business began to suffer. If you have agents, they must live, but perhaps it may some day be made the practice for those who desire insurance to go to the offices, as they do to banks, when the proper time arrives, so that the work of the agencies may be lessened, and the way opened for consolidation in fewer hands.*

The premiums received by companies doing business in Canada now approach twelve millions of dollars, thus divided:—

Nine Canadian companies.....	$2,282,497
Nineteen British "	7,334,432
Eight American "	1,767,831
	$11,384,760

* This used to be done a hundred years ago and we may have to revert to the practice:—The following, from "The Times" of 1804 relates to the old custom:—

Phœnix Fire Office, Sept. 14, 1804.

PERSONS whose Insurance Payments fall due at Michaelmas, are requested to take notice, that Printed Receipts are now ready at the Office in Lombard-street, and at the newly-erected Office at Charing-Cross; and with the several Agents of the Company in the Country.

GENERAL RATES OF INSURANCE.

Common Insurances.—For Sums not exceeding £3000.—2s. per Cent. per annum.
Hazardous Insurances.—For sums not exceeding £3000.—3s. per Cent. per annum.
Double Hazardous Insurances.—For sums not exceeding £3000.—5s. per Cent. per annum.
The Rate of Premium upon the Warehouses and Merchandize in the Isle of Dogs is reduced to 3s. per Cent. per annum.
Insurances in America, the West Indies, and on the Continent of Europe, are effected upon terms correspondent with their several risks..
By an Act of Parliament which passed in the last Sessions, an additional Duty of Sixpence per £100 per annum, will take place on the 11th of October next.

THOMAS WORSLEY, Sec.

N.B. No charge will be made by this Office for Policies of Insurance upon sums of £300 or upwards.

The losses (not including 1904) vary from $39\frac{1}{4}$ per cent. of the premiums of the year, in 1902, to $225\frac{1}{2}$, in 1877. The next highest loss was $93\frac{1}{3}$ per cent. in 1900. The striking inequality tends to prove that the Canadian field is not large enough to establish an average year by year. Some local drought, some city conflagration happens at uncertain intervals to disturb the regularity of business. Hence the necessity for large capitals and perhaps for special reserve funds, and we have seen even these impaired or dissipated by the adverse experience of a few years. It is indeed questionable if the business of all North America will make a company sure of a steady average, for similar financial and even meteorological conditions occasionally affect large areas, such as the basin of the great lakes. There has been an agitation in favour of municipal insurance, of which we hear some echoes even yet. As providing a very large capital, viz.: an appreciable part of the assessment of all the cities and towns entering into the business, it has a certain merit; as a means of reducing the premiums for insurance, which is the main object aimed at by its advocates, the above figures shew it can have none. Perhaps, if building by-laws were made stringent and were strictly enforced, if the insurance of buildings were made compulsory and confined to a certain limit, the premium being collectable with other taxes, there would be a profit to the department charged with the administration of insurance affairs, but it could not fairly be used in reduction of premiums for a long time because of the conflagration danger in an acute shape. If a municipal office were established there would be less inducement for companies to continue in business here, there would be a withdrawal of insurance capital and consequently even more difficulty than at present in keeping large stocks of goods properly "covered." To extend municipal insurance to goods is almost an unthinkable idea, also the application of it to the machinery and the contents of large factories, for an essential feature of the scheme is the assumption of the whole fire risk of every hazard, otherwise it is only playing at insurance, merely adding another to our numerous companies. The danger would be manifold, the risks would be too heavy even for municipal capitals available, which are far from being the total assessed value of property liable for taxes. Debts and other responsibilities must be considered, also the ability and inclination of the population to pay additional taxation, should a fire like that Toronto has this year suffered from require it, a loss officially placed at seven and three-quarters of millions of dollars insured, about equal to the insurance loss at St. John, N.B., in 1877. There would be danger from the want of elasticity inseparable from a bureaucracy, red-tapism annoying to the insured, and of the corruption which seems a necessary part of public institutions, which would be imputed if not proved in matters of settlement. Municipalities have enough to do, in relation to fires, to make and enforce

reasonable common sense by-laws as to building, and to provide plenty of water and efficient fire-extinguishing departments. They should indeed welcome suggestions made by responsible companies for the improvement of their fire prevention systems, but the companies may easily go too far, and sometimes do so when they dictate what must be done, under penalties. The proper way, it seems, is for the companies to measure risks as closely as they can, under the circumstances which exist, and to charge accordingly; it is for the citizens to desire and adopt proper means of protection, when legitimate competition will regulate premiums.*

Owing to frequent variations in mercantile and manufacturing hazards, fire insurances thereon are made from year to year. Upon dwellings and their contents three years is the customary, and, in Canada, the legal limit. The terms of fire insurance policies have become very liberal of late, e.g., losses by lightning are often covered, though no fire ensues, and as we may fairly say that an honest claim is sure of equitable settlement, free from technicalities, the relations between insurers and insured are, as they should be, very satisfactory.

Marine insurance is of two principal kinds, on the hulls of vessels and on their cargoes and freights. It is here divided† into ocean and inland marine insurance, for there is a large and increasing number of vessels navigating our Great Lakes and connecting channels. The same difficulty in establishing an average which fire companies experience prevails in inland marine and all St. Lawrence business, for dangers depend largely on the weather, which differs every year, and a particularly violent storm, such as occasionally sweeps the lakes, river and Gulf, from the head of Lake Superior to and beyond the banks of Newfoundland, accompanied most of the way by snow or sleet, is sure to leave disaster in its track, notwithstanding the storm-warnings, which are very useful and very often disregarded. Hulls are usually insured for the season or the year, but at sea they are often covered for the voyage, which may last even longer. Cargo risks "run off" much faster, resembling short term risks in fire business. Over-due ships become the subject of what looks like betting, and war-risks are beginning to be known again. The headquarters for marine insurance continues to be at Lloyd's, which was at first a coffee-house where ship-owners and mariners used to meet. It is now not unlike the New York Stock Exchange in its general features. The first notice respecting Lloyd's is dated 1688. In 1768 we hear of "the amazing progress of illicit gaming at Lloyd's

* If any city or group of towns should feel itself oppressed, a temporary syndicate could be formed on the mutual principle, which would charge the same rates as the companies, but, after accomplishing its object, viz., the reduction of rates to a fair tariff, would wind up and, after paying liberally for the use of capital, divide the surplus among the insured. Such a syndicate working without canvassers or other agency expenses, would have better and more immediate results than any kind of municipal insurance.

† At the harbour of Montreal.

coffee-house," where "men's lives" were the subject of this "detestable practice."* There is no time to descant on the growth and methods of i surance at Lloyd's, which afterwards took up handsome quarters in the Royal Exchange, but I will transcribe from Mr. Henry M. Grey's book "Lloyd's, Yesterday and To-day," a few lines which may interest the curious:—It is a form of policy.

"In consideration of three guineas for one hundred pounds, and according to that rate for every greater or less sum received of William Dorrington, we who have hereunto subscribed our names do * * * assume, engage and promise that we respectively * * will pay or cause to be paid unto the said William Dorrington the sums of money, which we have hereunto respectively subscribed, without any abatement whatever.

In case Napoleon Bonaparte shall cease to exist or be taken prisoner on or before the 21st June, 1813, commencing from this day.

London, 21st May, 1813.

£100. R. HEATH. One hundred pounds. 21st May, 1813.

£150. ANTHONY FINN KEMP. One hundred and fifty pounds. 21st May 1813.

£150. B. I. MITCHELL per Anthony Finn Kemp. One hundred and fifty pounds. 21st May, 1813."

By this you will see why insurers are called *under*-writers, and I may add that the word policy is said to be derived from *pollex*, the thumb, for when Lloyd's began business, some underwriters could not write, but made a thumb mark on the paper, *pollice*, thus anticipating Bertillon in his method of identification. At Lloyd's all manner of risks have been and can yet be insured—loss from riots, which is excepted from fire policies; loss from housebreakers, a very old form, ranking in years with "assurance from lying," "assurance of female chastity," and the like, products of the South Sea Bubble speculation. Dicky Thornton paid another underwriter £1,000 for each child the late Queen bore, and was to receive £20,000 if she ever gave birth to twins. And by the way, insurance against one's wife having twins is not unusual for those whose means would not stand the double strain.

In marine insurance, the practice is much more strict than it is here, in fire. The assured must keep within the four corners of his policy, or lose his recourse. If a vessel on our lakes is insured, let us say to December

* The prejudice against life insurance, as leading to murder and suicide and as being an attempt to nullify the designs of Providence may still linger among certain people. It was quite common when the writer was a youth.

3rd, with a condition that she is to leave her last port of departure before noon of December 1st, and actually leaves an hour later, the policy is voided. Or if a ship on salt water enters a port where pilotage is the rule, she is unseaworthy without a pilot, and cannot recover if she runs on the bar going out in charge of the captain, even though the latter may have weighed anchor in the belief that a pilot was coming on board. Policies often insure not only damage to the vessel, but under a collision clause cover damage to the other vessel or even the wharf the ship may collide with. Hulls are sometimes insured to their full value, though a margin is desirable, under which the owner is a co-insurer. Lloyd's has over 1,500 agents at the principal ports of all countries, who report arrivals and departures and usually take charge of damaged vessels and goods. The bills for losses and expenses are put into the hands of marine adjusters, who peruse the "protest" or account of the accident and distribute the loss according to recognized precedents and rules.*

There are no ready means of ascertaining the amount of ocean marine business done in Canada. Practically, all exports by sea are covered. In inland marine, $17,676,487 was the amount of all policies taken in Canada in 1903, and $76,941 was the net cash received for premiums, and the losses incurred were $25,902. There was also a large business done in "inland transit."

When we come to the consideration of life insurance, a new element enters into our calculations. It is of course possible, as in the instance of the policy on Napoleon's life, just above alluded to, to insure from month to month, from year to year, or for a term of a few years. This was indeed the common form of insurance wagers upon life in the infancy of the business, and the bets, which were sometimes grossly immoral, were usually made between individuals. I myself remember a case in Canada in which a gentleman bought a farm and agreed to pay the owner or his widow so much a year for life. I visited the widow when she was 103, blind, but a good talker still, and an inveterate smoker of *habitant* tobacco. The *heir* of the insurer had been paying the annuity for twenty years then! But the statute of George IV. against gambling insurances turned the current of business in the direction of the companies which were then taking shape, and it became the custom to insure for sums payable at death. At first, age was not much considered; a hale old man was thought as likely to last for a year or a short term as a younger one. But when all-life insurance came into vogue the system was adopted of paying equal sums, yearly or oftener, these premiums increasing with the age of the insured at entry—the new element being the rate of interest at which these premiums could be

* It is a curious fact that there are large marine insurance companies in Switzerland, a country without a sea-board,

invested, which, considered in conjunction with the tables of mortality, afforded a clue to the rates properly chargeable.

The first tables of mortality were made by the celebrated English astronomer Halley, and published in 1693. They were based on observations as to the duration of life at Breslau, Germany. The first tables of premiums were prepared from English mortality returns of 1741, for the Equitable Society, and were revised twice, once according to the London bills of mortality and again according to the deaths in a Northampton parish from 1735 to 1780. These Northampton tables had a considerable vogue and were a credit to the patience and ingenuity of Dr. Price, who prepared them. A still better system was, however, introduced by Mr. Joshua Milne, actuary for the Sun Life Assurance Society, based on the records for nine years, 1779-87, of two parishes in Carlisle. These tables took into account the numbers living as well as the deaths, they came into general use, and I think they are more in accordance with Canadian mortality than any others. The majority of insurance companies deal only with medically approved lives, a practice which calls for a different standard, which has been supplied by the experience of twenty companies, collected by the Institute of Actuaries, and in several other ways.

A new life insurance company, therefore, has to consider first by what tables of mortality it will be guided, next what rate of interest it will use in its premium calculations, and having thus established its net rate it must add enough to cover expenses, which is called loading. Profits are made by investment at a higher rate than that assumed and by exceeding care in the selection of lives for acceptance, which involves examination of the person offering himself for insurance by a capable medical doctor, and a scrutiny of his personal record and family history by the company's manager and directorate. It goes without saying that the expenses must be kept within the margin allowed, or capital will suffer. I have heard a good authority say that a hundred risks will establish a rough average, but it is of course safer to have a thousand, and still more so to have ten thousand. At first, all risks should be of moderate amount, none of magnitude taken on old persons, and as large an area of this little world should be at once exploited as the directorate can supervise. Life risks huddled together in one locality are as dangerous to a company's solvency as an excess of fire risks in one city block, for a steamboat accident, a theatre fire or even a bad epidemic may ruin a small local company. But, by attention to each of these important matters, of which security in investment is perhaps the most essential, our company may feel reasonably sure that, in spite of occasional alterations from average, the general result will be in accordance with calculation. A valuable contribution to actuarial statistics was made a few years ago by Mr. Sanderson, of the Canada Life, who prepared tables

of that company's experience, and compared it with the experience of several other leading companies. The differences shewn are remarkable, and seem to lead to the inference that our well-to-do people come of a hardy, long-lived stock. The life of the poorer classes in our city is, however, much inferior from an insurance point of view, not only because many trades are unhealthy but because the family history of the city mechanic is often lamentably discouraging.

Life assurance companies, like all other financial institutions, balance their accounts from time to time. To do so they must value their policies, that is, calculate the reserve which, together with future premiums—the whole invested at the assumed rate of interest—will provide for the payment at death, or other term agreed on, of the amounts the policies call for. This is done every year in Canada and the United States; in Great Britain a complete investigation with allocation of profits is only undertaken every five or seven years.

The question often arises whether it is better to apply for a policy with or without profits, and whether, after all, it is not wiser to invest savings in stocks, bonds, or mortgages. and I have been asked for my opinion. That depends so much upon circumstances that I cannot answer fully to-night, but I will submit a few facts. First I examine a policy taken out in 1873, without profits, premium $23.45 per $1,000. That sum, invested yearly at 5 per cent. would now have amounted to $1,765, or, at 6 per cent. to $2,124.* The assured is still paying his $23.45 annually, per $1,000, and if he wished to surrender he could perhaps obtain $500 per $1,000 cash, or a paid-up policy for $750 per $1,000. Next I look at a policy in a Scottish company which has been successful in its investments, netting quite $4\frac{1}{2}$ per cent. It is on what is called the *minimum* premium system, which is practically insurance without profits. This policy has run forty-two years and the premium is $17.44 per $1,000. If we allow $12\frac{1}{2}$ per cent for loading, the company has $1,815 in hand to pay each $1,000 covered, and has the interest on this sum as well as a large part of the $17.44 to receive as long as the policy holder lives. Had the assured invested the premiums here at 7 per cent. he would have had $4,022 for each $1,000. After this I examine a policy of the same age, with profits, premium $19.96 per $1,000, or $2.52 more than the other. The same person holds them both. The profits assigned are $265 per $1,000, which is $50 more than the $2.52 would have realized at 4 per cent., but it is only payable at death; the interest account would be realisable forthwith. Lastly, I scrutinize a policy which has run forty-six years, and was paid up by ten annual premiums. At 4 per cent. the sums paid would have amounted by this time to three times the face of

* To be exact, ten months' interest should be added, to cover the period since the payment of the last premium. The annual interest is about four times the premium, and yearly increasing.

the policy. It is of course necessary that the companies should make large gains on the policies of those who live long, for they must balance the losses on those whom death in some form, by accident or disease, early strikes off the list. But you will have gathered from the above that life assurance as an investment is of questionable advantage. The great utility of the system is the protection it gives to an active worker during the years when he is bringing up a family, and if he chooses to take one of the forms of endowment insurance, and thus unite some savings with that protection, there is much to be said in favour of that course, and little against it.

If you are not tired of such calculations I will give another instance, not dissimilar, communicated by an intimate friend. He has three policies:—

1. An all life policy in the —— Company (British) for £500. He has paid premiums for forty-five years, and entered at thirty-three. The premium I suppose to be about £13 per annum. He is likely to live several years yet, but the premium adds only to the company's resources, not to his policy. If he had steadily invested the premiums they would now have amounted to :—At 4 per cent., £1,636; 5 per cent., £2,178; 6 per cent., £2,931; 7 per cent., £3,974.

2. Of the second policy of $10,000 in the —— (American) he writes: I have been paying since 1870, and though I have been liberally dealt with by the annual reduction of premiums, this year the premium was increased by $45, owing, they say, to the paucity of profitable investments over 3 per cent."

3. "The third and last policy," he goes on to say, "$10,000 in the —— (Canadian) is the worst of all. This policy, taken out in 1877, called for $400 a year premiums, and, up to six years ago the premiums were reduced to about $320. Then, owing to the recent Dominion legislation, the premium has gone up to the original sum of $400. After paying this company $8,400 in premiums (I entered in 1877) they offered me a paid up policy of $3,500, payable at death only." The $320 invested would have yielded:—At 4 per cent., $15,065; 5 per cent., $17,504, 6 per cent., $20,384; 7 per cent., $23,840.

Then he inveighs against the companies, from whom he thinks, "no justice is to be expected" and says that "when death takes place the officials then try to discover some method of defrauding the survivors." Perhaps we may apply to insurance the proverb "Whom the gods love, die young." For there is no way of escaping without paying away more money without return, in the cases given, except to leave this mortal scene. I do not agree with my friend completely. I think he must be in error

as to the amount of the paid-up policy offered; the usual thing is to give a policy about equal to the sums paid in. I am not sorry to have lived longer than my expectation, and I contribute, not without a certain pleasure, to those families who are early left without a provider. I do think, however, that the legislation referred to was iniquitous. If the standard had to be raised, which I do not admit, having the best of reasons for knowing that the company complained of is using large sums in the North-West at 7 per cent., it should have applied to future entrants only, and those who have contributed to the company's reserve, should have had the benefit of it all.

When organising the statistics of Canada I could not obtain those relating to any branch of insurance, as there was no law to enforce the making of returns. I therefore prepared a bill to secure this end, which was introduced to Parliament by the Hon. Harcourt B. Bull. It failed to pass, through the opposition of some of the companies who did not wish their business made known to competitors. At that time foreign companies occasionally established agencies in this country, took money for premiums, and withdrew. Our policy-holders having claims were thus obliged to sue in a foreign jurisdiction for recovery, and sometimes found they were chasing a wildcat. So, after consultation with the Hon. Finance Minister Rose, afterwards Sir John, I prepared another bill, which not only called for statistical returns, but required all companies to deposit a reasonably large sum of money in the hands of the receiver general, attachable for Canadian claims. After a severe contest this bill passed and is the foundation of insurance legislation in Canada, though it has since been profoundly modified. It is surely not a betrayal of official secrets if I say now, for the first time, that another root of the deposit idea was the fact that the minister was at his wits' end for money, and was seeking suggestions for raising it. More anxious for my statistics than to raise funds, I informed him that a couple of millions could be had from foreign insurance companies, and, to cover up the appearance of its being a forced loan, I further proposed that a special issue should be made of Dominion stock, to be called class B, carrying a profitable rate of interest for the companies, to be issued at par to the amount of the deposit required, not to be transferable, but to be redeemable at par if the holders withdrew from Canadian business and paid or secured all claims. While Mr. G. F. C. Smith, then, as now, manager for the general agency of the London, Liverpool and Globe, opposed the measure as a whole, great assistance was received from him in adjusting its details. As a temporary arrangement, to suit American companies, approved securities could be deposited to secure a license for business, but were to be replaced by cash within two years. The British companies transacting life assurance business had a strong objection to making annual returns, but in the end this was overcome, and I had the pleasure of receiving

and handing to the receiver general about two millions in cash and bonds, while large sums were deposited with the government agents in England.

I was opposed to a system of government inspection, and am so still. I cannot see wherein insurance companies differ from mercantile concerns such as gas and electric light companies, steam and trolley railway and traction companies, trust companies and savings societies, which all issue long date bonds, for twenty or more years, and some sell perpetual obligations. It is evident that the absorption of the companies' funds in government securities at a low rate of interest tends to make insurance dear, for either the premiums must increase or the profits be less. It is also evident that depositing securities with an insurance department does not secure the solvency of the companies; that depends upon the judicious investment of funds by the directorates, and the care and economy of their management. There is expense connected with all government inspection, it comes ultimately out of the pockets of the insured, and we have seen that the expense accounts, both in fire and life business, are in need of reduction. Finally, a false confidence is instilled into the public, who imagine that if only a company has the government license, they need not scrutinize its annual financial statements. I understand that in Australia the companies are not in fetters as they are in the Dominion, in every one of its provinces, and in the states of the adjacent Union. Having advised against the formation of an insurance department, it was evident that if one were created I could not accept its superintendence, but, shortly after my leaving Ottawa, the office was founded and Prof. Cherriman became superintendent. The chair is now filled by Mr. W. Fitzgerald, who in his last report says "a revision of the insurance act at an early date may be considered expedient and necessary." It is probable that the laws will be made more binding and the inspection more effectual. I am at present doubtful of the efficacy of the government superintendence, that is, of the laws on which it is based, and I have not yet seen any official certificates that the fraternal societies, which are now doing a very large business indeed, have sufficient reserves to be solvent, or that their premiums are sufficient to provide for the liabilities they assume. Already four assessment companies make returns to the Dominion superintendent and several others probably do so to provincial officers. If there has to be an inspection it certainly ought to be thorough and complete.

The magnitude of the life insurance business in Canada is shewn by the following statistics, which I have extracted and condensed from the report of Mr. Fitzgerald for 1903.

LIFE INSURANCES EFFECTED IN 1903.

21 Canadian companies (excluding assessment companies)	$55,169,104
7 British " " " "	3,132,904
11 American " " " "	33,265,797
	$91,567,805

LIFE INSURANCE IN FORCE.

21 Canadian companies	$335,638,940
14 British "	42,127,260
15 American "	170,676,800
	$548,443,000

PREMIUM INCOME.

Canadian companies	$10,882,650
British "	1,435,318
American "	5,922,297
	$18,240,265

PAYMENTS TO POLICY HOLDERS.

Canadian companies	$5,516,779
British "	1,279,610
American "	3,491,975
	$10,288,364

DIVIDED THUS:—

Death claims	$5,960,423
Endowment claims	2,131,259
Annuitants	212,558
Surrenders	1,092,850
Dividends to policy holders	891,274
	$10,288,364

ACCIDENT INSURANCE COMPANIES, 12.

Premiums	$721,092
Claims paid	318,484

EMPLOYERS' LIABILITY COMPANIES, 6.

Premiums	$402,861
Claims paid	190,708

ASSESSMENT COMPANIES.

Amount of the year's certificates	$12,685,000
Amount in force	127,634,000
Payments by members	1,527,759
Claims paid	977,684

In addition to these we may perhaps class the employer's liability insurance companies, and the accident insurance companies, of which mention will be further made towards the close of this paper.

I have several times been called upon to examine into the sufficiency of the premiums charged by assessment companies to meet their inevitable death claims, and though I take an unusually broad view of the position

I have not found one solvent. Their premiums need not be so large as those of the old line companies, becanse they need less loading, as the expense of getting business is largely thrown on the contributories. Moreover, I do not think it necessary to value their liabilities at so low a rate of interest as the stock companies have lately adopted—much to the disadvantage of their clients who are concerned as profit-sharers. I am not of opinion that the rate of interest obtainable on investments will soon be further reduced. It is, however, not my intention to discuss the affairs of assessment companies now, and I have designedly forborne to examine the rates and reserves of the large societies, which I suppose have actuaries of their own. I will therefore pass to the consideration of sick benefit assurance as practised by fraternities, inviting special attention thereto.

I was engaged last spring in valuing the assets and liabilities of a set of lodges formed for this business, and found a very undesirable state of affairs. As there seems to be a movement for the extension of such insurance, some words of information and warning may be of public benefit. I intend to treat of the subject from the fraternal standpoint, though joint stock accident companies have slid into something very similar, for, whereas they at first paid claims for such accidents only as broken limbs, bruises or sprains, they now consider diseases accidents, and assure against death or disability from smallpox, diphtheria, and twenty or thirty other ailments.

The various trade-guilds of the Middle Ages were accustomed to support their members in sickness and to provide for the burial of indigent initiates, but, in modern times I think the first organized attempt to meet loss from illness was made by the Independent Order of Odd Fellows, Manchester Unity. This body had the good fortune to secure the services as corresponding secretary of Mr. Henry Ratcliffe. He made and published the first investigation into the sickness and mortality of the order in 1846-48, and completed two others for 1856-60 and 1866-70. The monetary tables deduced from this last experience remained standard until Mr. Wm. Sutton, actuary to the Friendly Societies, Registry Office, shewed that the sickness disclosed in 1876-80 was distinctly greater than that of any standard previously accepted. (Digests of the quinquennial returns of these societies to government had been made by Mr. F. G. P. Neison* and by Mr. Finlaison.†) Meanwhile the Ancient Order of Foresters Friendly Society resolved in 1878 to tabulate their experience for 1871-75, employing Mr. Neison. I understand that there has been a subsequent valuation for 1876-80,‡ but the tables for 1871-75 are the latest Foresters' I have at command. I have, however, the report of Actuary Alf. W. Watson on the experience of the Manchester Unity for 1893-97, published in 1903.

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* Contributions to vital statistics,1846.
† Parliamentary return, 1852-3.
‡ See statement on his page 89.

To plunge *in medias res*, let me give a sample table of one of these fraternal societies:—

Contributions to be paid for sick and funeral benefits, viz:—$100 at death of member, $50 at death of member's wife; $4 per week for first twenty-six weeks' sickness; $3 for the next twenty-six weeks, and $1.50 for continuation of illness.

Age last Birthday.	To Sick Fund.	To Funeral Fund.	To Management Fund.	Total Monthly Payments.
16 to 22 years	$0.31	$0.09	$0.25	$0 65
22 " 24 "	.32	.11	.25	0 68
24 " 30 "	.34	.13	.25	0 72
30 " 35 "	.36	.15	.25	0 76
35 " 40 "	.41	.16	.25	0 82
40 " 45 "	.48	.18	.25	0 91
45 " 50 "	.57	.20	.25	1 02

In the society using these figures the central lodge receives the funeral fund and is liable for the death claims, while the subordinate lodges administer the sick funds. Thus the central body may be solvent and the local ones insolvent. But we need not criticise the method of organization now. It will be seen at once that these contributions do not approach in magnitude, severally considered, the sums paid to life insurance companies by the wealthier classes, but when it is remembered that there were 673,394 members of the Manchester Unity at the date of the report last mentioned, not to speak of other orders, the importance of the subject to the poorer classes in England becomes manifest, and it may soon become of importance here also. For there is an increasing desire, born of increasing need, among our wage-earners, to render themselves and their families as much as possible independent of the expenses of sickness and burial, which are really crushing to those who have to live from hand to mouth, as the majority must. They feel that provision against both temporary and permanently disabling illness and against the cost of burials, which are ridiculously and extravagantly expensive, must be made in some way. All methods are reducible to one of three. The first is voluntary payment to fraternal or other benevolent societies, the beneficiaries contributing the funds by small instalments, the societies acting as trustees. The collections and disbursements are in such cases often made through subordinate societies, affiliated more or less strictly with a central body. Allied to this mode is the entrusting of the contributions to incorporated stock companies, which undertake all the responsibility of management. The second consists in a guarantee by the state, and as all plans involving it require that payments should be made to everyone on reaching a certain age, the whole method is popularly called the Old Age Pension system. Those who have not studied this arrangement as carried out in Germany and some other European countries, generally

think that government provides the pensions, whereas when we presently come to examine German practice we shall see that all the state pays is a small subvention. The third method is a frank dependence upon various forms of municipal and private charity, which happily always have been and will be supplemental to the others. It does not seem to me at all destructive of a man's self-respect if, after a life spent in hard work and in rearing a respectable family, he has at the end to accept the ministrations of good Samaritans, paying himself or by his relatives whatever he may be able, however little.

As in the duration of life there are general laws of mortality from which there is no escaping, so in sickness the laws are definite and strict.

FIRST LAW. First, I place this, that after our constitutions have "set," say at a little over twenty-five years of age, the annual percentage of sickness steadily rises. In other words, we become increasingly liable to illness. The percentage of those who made sick claims during each year among the 673,394 persons above mentioned was:—

Ages.	Per Cent of Claims.	Ages.	Per Cent of Claims.	Ages.	Per Cent of Claims.
16 to 19	28.66	40 to 44.....	25.48	65 to 69.....	49.21
20 " 24	24.45	45 " 49.....	27.06	70 " 74.....	60.60
25 " 29	23.49	50 " 54.....	29.51	75 " 79.....	73.18
30 " 34	23.62	55 " 59.....	33.70	80 " 84.....	85.15
35 " 39	24.08	60 " 64.....	39.81	85 up.....	94.01

SECOND LAW. A second law is that with increasing age, illness becomes more lasting. In other words, we lose our recuperative powers, and the constitutional weakness we inherit becomes more burdensome, or the ailment developed in us grows more serious. This is shewn by the average number of weeks of sickness claim made by the same body of contributors, which was:—

Ages.	Weeks' Sickness.	Ages.	Weeks' Sickness.	Ages.	Weeks' Sickness.
16 to 19	3.20	40 to 44.....	6.22	65 to 69.....	21.51
20 " 24	3.67	45 " 49.....	7.34	70 " 74.....	28.71
25 " 29	4.07	50 " 54.....	9.31	75 " 79.....	34.36
30 " 34	4.51	55 " 59.....	11.94	80 " 84.....	37.90
35 " 39	5.25	60 " 64.....	15.84	85 up.....	38.87

Thus while in youth good health is the rule, and disease is quickly thrown off, we are forcibly reminded of the Scriptural admonition that after three-score years and ten life is vanity and vexation. Individuals may escape with scarcely a day's illness until over four-score, but on the average there is a steady progression in misery from this cause.

THIRD LAW. A third law relates to the insanitary nature of various occupations. The sum of sickness in England at the ages from sixteen to seventy-four, taking the average of five years, embracing over three million years of exposure, in which there were seven million weeks of sickness, worked out as under:—

Occupation.	Absolute No. of weeks sickness.	Ratio to Class I.
1. Agricultural and non-hazardous	236.3	100
2. Building trades, railway service and sea-faring people	284.8	121
3. Quarry men, iron and steel workers exposed to great heat	325.5	138
4. Miners	410.0	173
Whole society	251.7	106

Allied to the above is the question of residence. By this experience the duration of life was about two years greater in rural than in urban districts. City mortality was in excess of that in towns. Mr. Watson says: Of 1,000 members entering observation at sixteen years of age there are still living at sixty-five in

Area 1 Rural	588	Area 1 Urban	554
" 2 "	506	" 2 "	455
" 3 "	557	" 3 "	514

Area 1 rural is almost exclusively agricultural, area 2 urban is the Cheshire, Lancashire and West Yorkshire region of the textile industries. Comment is unnecessary here. There is more sickness in urban than in rural districts.

FOURTH LAW. Then there is a fourth law I think I may lay down: viz., that disability from accident increases with age, but not in a steady ratio. I take this from the German statistics, which are as follows:— Accidents per 1000 insured.

Age.	Industrial Building Trades and Marine Accidents.		Agricultural and Forestry Accidents.	
	Males.	Females.	Males.	Females.
16 to 18	3.6	1.6	2.8	1.5
18 " 20	4.3	1.3	2.6	1.5
20 " 30	6.2	1.6	3.0	2.1
30 " 40	10.1	1.9	4.4	4.9
40 " 50	13.6	2.5	6.6	6.8
50 " 60	15.3	3.2	8.1	9.1
60 " 70	16.0	2.6	10.4	10.3
70 and up	9.9	1.1	8.9	8.4

The German authority, Dr. Klein, says it is evidently not customary to put young people in charge of dangerous work, and this is why an increased percentage of accidents is shewn when workmen reach the prime of life. I

should rather attribute the increase to the diminution of physical and mental activity as the working man wears out.

It was my hope to have been able to tabulate enough Canadian data to form an idea of sickness and death rates among our working classes, but the basis obtainable is not broad enough. As far as I can conjecture from the statistics laid before me, the Canadian mechanic's life is somewhat better than the English, and the sick claims appreciably less, age for age. We have, however, as yet only the younger ages to observe, of persons who have not reached the years when illness becomes disabling for long spells.

Having established the fact that sickness follows numerical laws as closely as mortality, and as I find, even more definitely—having come to know that by these laws there are both more and longer periods of illness with advancing age until total disability to work occurs, (such total disability arising practically when the periods of illness become frequent)—it becomes plain that a society aiming to pay a weekly sum in lieu of wages, which cannot be earned, must not depend upon good-will or other assessments, it must have reserves. The table of contributions given earlier shows that three times as much is paid as premium for sick benefits as to the funeral fund, and valuation shews that the necessary reserves to ensure safety for the sick benefit fund must be three times as large as for the funeral fund. I wish I could say they were so in all our societies. In discussing the subject with those interested in them, the argument has been used that as our lives are better, i.e., longer on the average than those known to English experience, and the sick claims, so far, less, then, ceteris paribus, a smaller premium should suffice here. The reasoning is, unfortunately, unsound. A more favourable death-rate and the higher rate of interest obtainable here have indeed a beneficial effect on the funeral fund, which is a species of small joint-life insurance for husband and wife, but, owing to the separation of the two funds, which ought not to be countenanced, that does not help the sick benefit fund, while the more favourable mortality simply gives a longer term during which the heaviest payments for sick benefits must be continued. On this subject Mr. Watson says:—(p. 45),

"If the death rates be uniformly *above* a common standard, a society will gain by its release from a proportion of the anticipated sickness-benefit liability; but, on the other hand, it will lose, firstly by the 'premature' payment of death benefits and consequent loss of interest on the capital thus withdrawn, and secondly, by the contribution income gradually falling below the amount anticipated by the standard. If the death rates be uniformly *below* a common standard, the effect on the finances will be in each case in the contrary direction, the sickness claims being

ultimately increased, the payment of the death benefits postponed, and the anticipated interest and contribution income augmented. In either case the effect upon the sickness claims will be much greater than that upon the interest and contribution income. The net result of a high death-rate may be summed up, therefore, as diminution of liability, and that of a low death rate as augmentation of liability."

What ought to be done to meet, honestly and justly, the desire to secure the benefits in question through fraternal organizations? Clearly this, to make the premiums adequate to the benefits. The societies say that if this is done, the membership will fall away. Even in the largest of these which collect assessments for the purpose from their members generally, there was last summer, at the Toronto convention, a division on the subject of raising rates, which an exhaustive report shewed to be necessary, and the result was that the proposal to raise the assessments was defeated and the report was "not received." This, as I understand the facts, but information is difficult to obtain. The table of actual rates I have copied above would provide almost enough for the funeral fund, if the money collected were placed at once in safe hands and properly invested on mortgage security at current rates. But that for sick benefits would come woefully short.

Taking the case of an entrant at twenty-five years of age, who would pay thirteen cents to the funeral fund and thirty-four for sick benefits, the liability to pay for his funeral should at once be estimated (4 per cent.) at		$29 37
Also for his wife's funeral claim (same age assumed)		10 02
The liability to pay $4 a week for his sickness, not lasting over six months is		82 66
The risk of paying $3 a week for the second six months costs		9 94
And that of disbursing $1.50 a week for the rest of his period of illness is		15 76
		$147 75
To meet these anticipated claims the society has his premium payments for life, or, say a value of $18.01 for every dollar, i.e.:—		
For sick funds	$73 48	
For funeral fund	28 09	
		101 57
The society therefore incurs a *liability* of		$46 18

for every member admitted at twenty-five!

If now we divide this deficiency by $18.01 we shall at once see that the quotient, $5.64 a year, or say $0.47 a month, marks the additional sum which the entrant at twenty-five should pay. The management fee, which is nearly 35 per cent. of the total paid in, could be easily reduced by enlarging the number in each lodge, and then perhaps the members might contribute at the age mentioned $1 a month, instead of

$0.72, being:—For sick benefits $0.64; funeral benefits $0.21; expenses $0.15.

The full table I have calculated is as follows:—

MONTHLY PAYMENTS.

Ages at Entry.	For Sick Benefits of $4 a week for first 6 mos.; $3 for second 6 mos.; $2.50 for remainder of life.	For Funeral Benefits of $100 at death of husband; $50 at death of wife.	Expenses of Management.	Total.
18 to 22	$0.46	$0.15	$0.15	$0.76
22 " 24	0.55	0.17	0.15	0.87
24 " 30	0.64	0.20	0.15	0.99
30 " 35	0.74	0.25	0.15	.14
35 " 40	0.87	0.30	0.15	1.32
40 " 45	1.03	0.35	0.15	1.53
45 " 50	1.22	0.40	0.15	1.77

With malingering closely watched, I think these rates would suffice. In England the experience given by Neison is:—"Taking an average society, with a normal admission of new members, in the course of five years nearly one half of the members may at one time or another be expected to make a claim upon the sick fund, whilst during the period about 5 per cent. of them will die." I quote this to show how constant and serious the claims of both kinds are.

I have personally felt, though only to a slight extent, the sting inflicted by the failure of one life assurance company; I have known of distressing cases in connection with the increase of assessments made by another; the responsibility of accepting too low a scale of premiums is very great and I hope these few calculations, which I could supplement to any extent, for I have been interested in the laws of sickness for a very long time, may do good both to existing and projected societies. If we are to have workmen's insurance, let it be as cheap as facts will warrant, but let it be sound.

Some rely on lapses—that is, policies discontinued—to restore the financial balance, but it is a weak reliance. Lapses do not benefit any class of life insurance company, under ordinary circumstances, and least of all a sick benefit society, for those who fear illness are sure to retain their membership, and the best blood of each society is that which lets insurance and sick benefits go. Though the strongest should reflect that accidents, such as are met with in travelling, on foot, or by rail, or fractures of limbs in following trades, also these arising from disease germs which are met one hardly knows where, being carried in the money we earn, the milk or the water we drink, or the kiss we receive, do not occur to the weak alone.

I conclude with a short reference to the German system of compensation for accidents and for old age pensions.

The last time I met the Hon. T. D'Arcy McGee, (just before his assassination) I enquired what he had been doing to occupy his mind since his relief from political duties. He said he had been giving thought to matters of education, and had been reading Wilhelm Meister. To an enquiry what he found admirable therein, he replied that he was much impressed by a passage which declared that if one set a number of people in line and bade them put out the right arm, all together, at the word of command, the discipline had an educational value, as teaching them mutual reliance and training them to act in concert. I answered that it might also impair their capacity for individual action and lead to subserviency to arbitrary power. We did not pursue the subject, but similar considerations arise when we examine the German methods of providing for old age and contrast them with those of Great Britain, or even our own.

The system of workmen's insurance in the German empire is called a "work of conciliation and social reform." A bill for the insurance of workmen against industrial accidents was laid before the Reichstag or Imperial Diet in 1881 by a message from the Emperor, to impress upon that body, "the necessity of furthering the welfare of the working people," to "render to the needy that assistance to which they are justly entitled." With it went also a measure providing for a general organization of industrial sick relief insurance, and an intimation that a plan ought to be devised for giving succour to those who suffered from invalidity (inability through illness to work) or old age. These three branches are still kept distinct, but after several changes and extensions, the regulations were consolidated by the legislation of 1893.

I.—Accident insurance covers all workmen on wages, and with them are classed clerks and officials with salaries not exceeding 3,000 marks ($750). It is paid for exclusively by employers, and the compensation includes free medical attendance, medicines and medical appliances, or, as an alternative, free hospital treatment, during the whole cure. It carries with it sick pay of two-thirds of the yearly wages, from the beginning of the fourteenth week after the accident (in continuation of the sickness insurance), and, in case of a fatal result, funeral expenses up to one-fifteenth of the yearly earnings, but not less than fifty marks, and a pension for widow or widower and children, or for parents or grandchildren, up to 60 per cent. of such yearly earnings. The employers probably consider this cheap insurance, for it replaces the liability to claims at law, which is here commonly covered by workmen's insurance in accident companies. The employed have the advantage of feeling that as the pay comes from the

employer, precautions will be taken for mutual benefit. The claim is met, not by the one employer, where the accident occurred, but by the united funds.

II.—Sick benefit insurance is managed by clubs, thus:—(1) Local sick-clubs, established by townships. (2) Industrial sick-clubs established by owners of large factories. (3) Builders' sick-clubs, established by contractors. (4) Guilds and (5) Miners' sick-clubs, governed by the laws and regulations of the various states and, (6) Townships sick insurance comprehending all not covered by the other clubs. Like accident insurance this is compulsory, but in sick-benefit insurance the workpeople pay two-thirds of the contributions, up to 4 per cent. of the daily wages, the employers pay the other third. Voluntary sick-clubs are permitted, in which the workmen pay the whole. The relief is free medical or hospital treatment and sick-pay for twenty-six weeks of half the usual daily wages. For women during confinement six weeks are allowed at this rate. In case of death, twenty times the daily wage is allowed for funeral expenses. Double insurance is permissible and the sick clubs are allowed to extend sick relief for twice the above time even without such additional insurance.

III.—Invalidity and old age insurance is the only form in which the state gives any contribution, and that contribution is small. The funds for this object are provided by weekly contributions, paid half by employer and half by the employed. The Imperial government adds fifty marks ($12.50) for each person insured. All such are divided into five classes, according to the amount of their yearly earnings, those who earn up to 350, 550, 850, 1150 marks and above that sum, and the pensions are in two orders, those who are seventy and still able to work and all who are not. Calling these orders (a) and (b) the pensions are graded among the five classes thus:—

Class I.	Earnings up to	350	marks	(a)	110	(b)	185	marks
" II.	" "	550	"		140		270	"
" III.	" "	850	"		170		330	"
" IV.	" "	1150	"		200		390	"
" V.	" above	1150	"		230		450	"

Payment of the contributions is usually made by the employers, who buy stamps of a special kind from the local office, affix them to the receipt card of the insured, and charge the cost to the employed. The amounts are in due time paid in to "insurance institutes" whose boundaries coincide with province or state divisions, and they manage the funds independently of each other. The officers of the board of direction, of the managing committee of these institutions and of arbitration courts connected therewith, are honorary and unremunerated. Expenses are paid, and, in the case of workmen's representatives, compensation for loss of wages also.

The system is not perfect, because of the division into the three great parts enumerated, and they will probably soon be united, so that the accident, sickness and pension business may be transacted by one set of directors and officials. An extraordinary latitude in investments has also been allowed, for instance, the institutes are in many cases owners and even builders of workmen's houses. The annual cost of the whole system is expected to be (in a state of permanence, not yet reached because in accident insurance the pension list, to be met by assessment, is still rising):—

	Employers Contributions.	Employed (paid by.)	Empire Pays.	Total.
Sickness Insurance	5.15	10.30	....	15.45
Accident "	6.08	....	....	6.08
Invalid "	4.65	4.65	2.88	12.18
Marks	15.88	14.95	2.88	33.71
Or, in dollars	$3.97	$3.74	$0.72	$8.23

The expenses of administration have been as high as 12½ per cent. of the disbursements for all purposes. They are now stated at about 9½ per cent. thereof. Reckoning the ratio to receipts, as we usually do, they are about 7½ per cent.

A summary of the results of the system for 1902 is given as follows:

Total population 58,000,000. Wage workers 14,500,000.

Insurance Against.	Sickness.	Accident.	Invalidity.
Persons insured.....	10,320,000	19,083,000	13,381,000
" compensated.....	3,983,900	834,600	1,061,000
Receipts—marks.....	200,350,600	141,394,100	210,677,100
from contributions of Employers.....	58,624,900	125,663,300	69,492,900
Employed.....	130,784,000	.....	69,492,900
Expenses	194,060,000	124,796,900	132,361,800
including Compensation....	183,174,100	108,133,100	120,414,100
Costs of Administration.....	10,885,900	16,663,800	11,947,700
Accumulated Funds.....	186,645,200	199,194,300	1,007,477,500
Compensation per case.....	46.0	128.7	113.0
Charges per person insured.....	18.8	7.1	13.2

The mark is about equal in exchange to a quarter of a dollar, and to make the system applicable to Canada, where the standard of living is higher, we should have to at least double the contributions. But in spite of the pride with which German officials regard their methods, it does not seem to me possible that they could be made suitable for England, the United

States or Canada, at the present time. There is in the first place, the element of compulsion, which has always been distasteful to those of British origin. In the next place there is the element of inquisitorial supervision, in connection with various kinds of registration. The regulations appear also to hinder free movements from place to place, and obstacles are raised against leaving the country. The patronizing tone of the rescripts and of all the literature concerning the institutions of the system would be offensive to our people. It is the same with conscription for the army; the years spent with the colours are not without their advantages, but free Britons and Canadians will not submit to what the German soldier has to endure. Once adopted, however, it is like a great piece of machinery, it must keep on going, it cannot be abolished without universal loss.* I think we can develop our own systems, as required, to our greater satisfaction.

Whenever the government interferes, to pay sums of money for any purpose whatever, those sums, with a large percentage added for expenses, come from the pockets of the people, by raising the expense of living. And as for the compulsory payments exacted from employers, it is probable the Canadian workman receives as much compensation for accidents due to employers' negligence as the German artizan receives. About fifty cents per head of the population was paid in Germany for accident claims, in 1901, and only 40 per cent. of this was chargeable to the employers' neglect. It is not easy to make comparisons here, owing to the large preponderance of our agricultural population, especially in Quebec, among whom employers' liability companies are unheard of, but nearly $200,000 a year are paid in Canada for the consequences of accidents by these institutions alone. That is four cents per head on our total population of 5½ millions. Very large sums are paid through the arbitration proceedings of our law courts,† and the founts of benevolence are not dried up here as they might be by a blood and iron system like that just described. On this subject I need only quote a recent utterance of Mr. Adam Beck, the mayor of London, Ont.:

"We should be thankful for the efficiency and comprehensiveness of our hospitals and our charitable institutions. Where will you find better hospitals than in London, better charitable institutions than we have here? No case of sickness, of old age, or of want needs to go unrelieved in London. Our means for the alleviation of suffering are unsurpassed."

Some system will ere long establish pre-eminence here—fraternal, financial or national, and we may be permitted to hope that a noble view

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* Mobilitate viget, viresque acquirit eundo.

† For instance, here is a news item of this very week:—

Welland, Ont., Nov. 21.—Several actions brought under the Workmen's Compensation Act were tried at the assizes, which opened here this afternoon before Sir John Boyd. H. Cummerford, who was injured in a quarry at Sherkston belonging to the Empire Limestone Company, was given $1,000 damages. I. Fulford, brakesman, who lost two fingers in coupling cars, received the same amount from the International Railway Company.

of their responsibilities will be held by those who may control it. If it is to be fraternal, which I favour, every table of rates and every annual statement should have the certificate of a competent actuary attached, to the effect that (1) the rates are sufficient according to the assumptions stated and that (2) the balance sheet has been made up in accordance therewith. These documents should be filed with the statistical officer of the government, and duly published. Legislation might provide that no society should receive contributions unless at a fair current rate of interest they would amount to the liabilities of the future. I think the societies should be provincial, not Dominion, so far as their organization and business are concerned, but Dominion legislation may be required to facilitate the transference of members from one province to another, carrying with them proper assets and liabilities, from one company to another, in case of permanent removal.

Savings for sickness or old age made in these societies might be guarded against seizure or hypothecation, up to a limited amount. They should not be invested, to please the government, in low-interest bonds, but allowed to earn good interest on sound mortgage security. There is no need for the government to have any of their property in its safes. The expenses should be controlled by strict rules, and in case of extravagance or failure to realize the assumed rate of interest, there should be an automatic method of resting all the property in a government commissaire, who should transfer the assets and liabilities at a fair rate to another solvent society or compel the formation of a new society under different management. The management of the societies has heretofore looked only to the financial conditions of their charge. There should be a system of care to prevent and to cure disease, and the object should be not to procure medical advice and medicines at the cheapest cost but to get the best help, as the most effective. Hospital nursing, convalescent homes, and what the Germans call household barracks, and recreation grounds must be developed, where those suffering from asthma, stomach and heart disease, hysteria, anæmia or the consequences of accidents, operations and inflammations may regain health. In this, municipalities would aid quite heartily, and so would generous individuals, and independence could be preserved by a contribution from the society for the cost of food, etc. In time the various needs should be met by the same society, or federation of societies, saving trouble and consequent expense. Life insurance additional to the funeral benefit should by each organization be supplied at cost, and it is not difficult to foresee that, by the aid of large accumulated capital, better dwellings could be secured for the thrifty mechanic or labourer and a variety of other benefits obtained.

In Memoriam.

REV. JOHN CAMPBELL, M.A., LL.D.
JOHN BERTRAM, ESQ., Ex-M.P.
OLIVER A. HOWLAND, C.M.G., K.C.
ARTHUR HARVEY, F.R.S.C.
KIVAS TULLY, C.E., I.S.O.
REV. NEIL MACNISH, M.A., B.D., LL.D.

The Canadian Institute has lost heavily during the past year by the deaths of the above-named distinguished members. The numerous papers of Professor Campbell contributed to the Transactions bear witness to his extensive attainments in Philology and Ethnology; Mr. Bertram was Chairman of the Transportation Commission and in that capacity performed valuable service to Canada as well as by his studies in Forestry; Mr. Howland was a diligent student of Canadian History; Mr. Harvey may be characterized as another "admirable Crichton," so wide was the range of his knowledge and so unwearied his labours in so many departments of literary and scientific research; Mr. Tully was eminent as an Engineer and a charter Member of the Institute; and Dr. MacNish was an ardent devotee in classical and Celtic literature.

NIELS R. FINSEN—HIS LIFE AND WORK.

By Charles R. Dickson, M.D., Toronto.

Electrologist to Toronto General Hospital, Hospital for Sick Children, St. Michael's Hospital; Fellow and Ex-President of American Electro-Therapeutic Association; Member of Canadian Institute, Etc.

(*Read 28th January*, 1905).

The beneficial action of light, not only in maintaining health merely, but also in combating various forms of disease, has been recognized from time immemorial in a general way, almost intuitively, and often unwittingly. Sunlight has ever been acknowledged a most potent restorative. The ancient Greeks were in the habit of anointing their bodies and thereafter exposing themselves unclad on the flat roofs of their dwellings to the direct rays of the sun, not only on the score of health, but also as a luxury.*

Vestricius and Cicero mention that the Romans similarly indulged in the sun-bath, followed frequently by cold sponging of the surface of the body. At a later period in their history they erected special outbuildings for the purpose, which they called Solaria and in these took their sun-bath, or Heliosis.

Herodotus especially advises sun-baths for those whose muscles are weak and flabby. Antyllus goes into the matter more fully still, detailing the effects of the sun-bath and its action upon the system, and directing in what diseases it may be found useful. Herodotus, C. Aurelian, and Antyllus recommend sun-baths in the treatment of diseases of the skin. And many other of the writers of antiquity have advised the use of the sun-bath as a curative agency in quite a wide range of diseases.

This early belief in the health-giving power of the rays of the sun is found among many nations and is well nigh universal. Natives of South and Central America and Mexico may be seen at mid-day stretched full length on their backs for hours at a time in the blazing tropical sun, as a remedy for consumption; a method which is said to antedate the advent of the Spaniards.† And in China, Japan, Hayti, and Mexico not only

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* Freund, "Radio-Therapy."

† Rogers, "Lucotherapy."

is the beneficial action of the sun's rays accepted, but the hurtful effect in certain cases is also known; thus, while sun-baths are given to some patients, others are kept from the light.*

Systematic treatment of disease by means of light may be said to date from the beginning of the nineteenth century, when Professor Lobel of Jena set forth in definite terms the conditions in which light treatment might be employed with benefit, and those in which it was to be avoided, and described a special apparatus by means of which such treatment could be carried out. From this time forward, much careful investigation has been carried on, and much patient work has been done in placing light treatment upon a scientific basis.

But it remained for the immortal Finsen to gather together these varied threads of evidence in favour of the powerful influence of light upon the health, to crystallize the many and most valuable discoveries of other learned men to whom he never failed to render due credit for their service to the cause of science, and to carry on his own most ingenious and extended series of observations, remarkable most in their strange simplicity.

Born on the bleak Faroe Islands, the greater part of his youth—until his twenty-first year—was spent in Iceland, the weird land of storms and wintry night, and strange contrasts of light and darkness, almost dramatic in their vividness. Even in his boyhood the effect of light possessed a great charm for him; he noticed the action the rays of the sun had upon some animals, and well he knew the depressing effects of sunless days. All this proved an incentive later on to study most searchingly the action and influence of light upon health.

When he graduated from the University of Copenhagen in 1890 as Doctor of Medicine, after spending eight years there, he was already a confirmed invalid, although only thirty years of age, in fact he had been in wretched health since his twenty-third year, and now his heart, liver, and organs of digestion were so hopelessly deranged that active practice of his beloved profession was absolutely impossible. Immediately upon graduation he was appointed Prosector of Anatomy at the University of Copenhagen under Professor Chiewitz; they still use at the Anatomical College a dissecting knife invented by him. For three years he contented himself with acting in the capacity of prosector at the University, and here we find him in 1893 in the little city of Copenhagen, poor, unknown, handicapped in body, but with keen powers of observation, the faculty of investigation highly developed, a rare intelligence, and with an indomitable will in spite of his almost constant physical suffering. From before the close of his student life he had been experimenting with light, always

* Freund.

keenly anxious to probe its mysteries, and now he has a story to tell, and the whole world of science waits to hear, sceptical at first, but convinced ere long.

To enter fully into the nature of the researches and experiments of Finsen, and all the discoveries which led up to them, while most interesting and instructive, would yet demand the presentation of an amount of scientific data incompatible with the time at our disposal, and the limits of a paper such as this; but, in order that the whole matter of his work may be fully comprehended, and yet be confined within reasonable bounds, it may be permitted to sum up briefly a few of the main theories, but only a few, upon which the experiments of Finsen were based; in a word, what was the foundation upon which he was to erect his splendid superstructure?

And, first, omitting all that led up to it, was the theory that light is composite in character, consisting of various coloured rays, and that when it is broken up into its component colours by suitable apparatus a beam of light appears to the eye as a band or strip of red, orange, yellow, green, blue, indigo, and violet, each shading off gradually and blending with many intervening tints into the succeeding colour; this colour series being termed the visible spectrum.

The rays of light are wave-like, and all the waves are not of the same length or height, nor do all vibrate at the same speed. The red waves vibrate the most slowly, only about four hundred billion vibrations per second, and the rate increases as we ascend the series until we find the violet rays vibrating at just double that speed, namely, eight hundred billion vibrations per second. The red rays, on the other hand, are the longest and least easily diverted from their course, or kept back, hence they pass most directly through a prism and appear at the foot of the spectrum, while the violet rays are of the shortest wave length, and are most easily retarded, and diverted, and being most bent out of their course in passing through a prism, appear at the top of the spectrum.

But these rays, red to violet, constitute merely the visible spectrum, for beyond and below the red rays, and vibrating still more slowly, too slow to be visible to the human eye, are other rays, termed infra-red, or ultra-red; and beyond and above the violet rays are others still, which are known collectively as ultra-violet, more rapid, too rapid to be detected by the human eye, and shorter and also more active than the violet, but, unfortunately, yet more easily diverted from their course and less penetrating.

There are many other differences in these varying rays, but differences

in degree only, not in kind. Thus, while all parts of the spectrum are capable of giving rise to heat, this quality is most marked towards the red and infra-red portion; also, while all parts of the spectrum are capable of giving rise to chemical changes, this action is most marked, as a general rule, towards the blue, violet, but especially at the ultra-violet portion. And so we speak in general terms, if not quite correctly, of the heat rays, meaning thereby the red rays, and of the chemical or actinic rays, meaning the blue and violet rays. Red glass allows the red rays of light to pass through it, but absorbs the chemical rays, not permitting them to pass. This is why the ruby light is used in photography when one wishes to examine a plate which would be spoiled if the chemical rays of daylight—"white light"—were allowed to reach it just then, but the red light is so weak in chemical action that it will affect the plate very slightly. Yellow has the same deterrent effect on chemical rays.

Much more than these bare facts was known to the world of science when Finsen, towards the close of his student life, began his experiments with light. His first investigations related to the injurious action of the so-called chemical rays of light, and with marvelous acumen he turned the researches of others to account; their results he was enabled to interpret, and their theories he was able to put to practical use.

In one of his earliest contributions to medical literature in 1894 he admirably states the position of affairs up to that time as follows: "It must be acknowledged that, with the exception of the influence of light upon plants and upon the organ of vision, our knowledge of the physiological action of light and its effects, whether good or bad, is very limited. In undertaking now the study of one of the properties of the chemical rays, viz., their injurious influence upon the animal organism, I do so, not because I regard this property as the only influence of the chemical rays, but because it constitutes the very foundation of our subject."* In July, 1893, he had set forth some striking theories with regard to the action of light,† and now he proposes to expound and elaborate them.

He draws attention to the fact that the deleterious or fatal influence of light upon the majority of bacteria (germs) is already known, that one writer, Duclaux in 1885 had said that "sunlight is the best, cheapest, and most universally applicable bactericidal (*i.e.* germ-killing) agent that we have," and others, for instance, Downes and Blunt in 1878 had shown that this effect was due almost exclusively to the chemical rays. It had been noted by Graber in 1883 that if earthworms (lumbrici) were placed in a box covered with strips of different coloured glass—using the colours of the spectrum—the worms always crawled to the darkest places,

* Finsen, "Phototherapy."

† N. R. Finsen, "Hospitalstidende," July 5, 1893

namely under the red glass, and Dubois in 1890 had shown that the proteus, an animal like the earthworm, preferring darkness, was least comfortable in white light.

In 1851 Brucke had explained that the chameleon changed its colour by means of pigment cells in its skin, which came closer to the surface in light, and in darkness lay deeper; a slow change from darkness to light producing a scale of colouring in the animal which became successively whitish, gray-green, then spotted with black, and finally brownish-black; the pigment cells in the skin of the animal being moved nearer to the surface to protect it against a disagreeable light impression. Paul Bert observed (1878) that red and yellow light had no influence on the pigment cells, while the blue and violet rays produce a strong reaction; and in 1887 he observed further that if one-half the body of a chameleon were illuminated through a red glass, and the other half through a blue glass, the half under the red remains for a long time whitish, while the half under the blue glass becomes almost instantaneously blackish.

Finsen had noticed that horses and horned cattle were subject to the so called "sun-burn" (solar erythema), as well as man, and many veterinary surgeons had informed him that this erythema was limited to non-pigmented parts of the skin, almost exclusively. Wedding in 1883 had described an interesting observation, the truth of which had been confirmed by Virchow, namely, that cattle and sheep fed upon buckwheat are subject to skin eruptions with the formation of vesicles, which was much more marked in the whiter animals and those exposed to the light or direct rays of the sun. Animals kept in the dark were not affected by the disease, and a white cow which had been coated on one side of its body with tar had the eruption on the opposite side only. An especially interesting observation had been made by Livius Furst, that when calves with a dark hide were vaccinated, in preparing animal vaccine, the pustules did not form well, and that consequently those with a light skin were preferred for the purpose. Volkmann in 1891 noted this fact as learned practically, but did not try to explain it.

Moreover, Unna of Hamburg in 1885, Widmark of Stockholm in 1889, and Hammer of Stuttgart in 1891 had definitely demonstrated that the chemical rays of the spectrum, and particularly the ultra-violet rays were responsible for erythema solare or eczema solare—commonly termed "sun-burn"—and the pigmentation of the skin of human beings —or "tanning"—and that these were not the effects of heat, for explorers in the polar regions and tourists on the glaciers, even when the temperature is below zero may suffer severely from "sun-burn," caused by the strong reflection of sunlight from the fields of ice. Widmark also demon-

strated that the inflammation of the skin caused by a very strong electric light was identical with erythema solare.

Finsen regarded pigmentation as nature's way of protecting parts from the injurious action of the luminous rays, the colouring matter preventing the rays from penetrating too deeply and thus protecting the skin against their inflammatory action. Finsen proved this himself apart from any one else, and not knowing that others were experimenting in a similar direction. He was trying to account for the cause of the pigmentation of the skin of negroes. To imitate the colour of the negro's skin he painted a band of Indian ink about two inches wide on a part of his forearm not usually exposed to the sun, and normally quite light in colour, and exposed the arm to a very hot sun for about three hours. He then removed the Indian ink, and the skin under it was quite white still and normal, while that on either side was red. After a few hours inflammation, pain and slight swelling developed and lasted several days, and finally the parts became fairly strongly pigmented, but the protected portion remained normal throughout, even the little irregularities in the edges of the black band being clearly defined. The arm was then again exposed to the sun, but without blackening it this time. The result was completely reversed; the white zone became the seat of the inflammation, while the parts on either side were not changed in appearance, except perhaps that they were a little more pigmented. Oarsmen who get their arms "burned" early in the season, find the protection of the subsequent "tanning" later on.

In animals, the surface most exposed to the sun is generally the most coloured; this is noticed in furred animals, whales, reptiles, birds, fish. Fish need this protection, because, while water absorbs the red and ultra-red rays to a high degree, it allows the ultra-violet to pass freely. "Among polar animals, pigmentation seems to vary in relation to light. There exists a connection between the black colours of the summer, which is so rich in light, and the whitish hues of the winter, which is so dark."*

Too much light is injurious to plants, and provision is made by nature to protect them in various ways, a colouring matter being deposited in certain cells for that purpose.

The acute effects of the chemical rays upon human skin vary from a feeble irritation through all degrees up to inflammation followed by exfoliation, depending upon the intensity of the light and the proportion of chemical rays which it contains. Ordinary lamps give proportionately less, and electric light more chemical rays than the sun. The intensity

* Finsen.

of effect depends also upon the duration of exposure, the amount of pigmentation of the skin, and perhaps the thickness of the epidermis.

This inflammation is unlike all others of similar duration, in leaving a pigmentation of the skin. Unlike that caused by heat, it does not develop immediately, and does not attain great intensity until from twelve to twenty-four hours after the exposure. It only develops upon parts directly exposed to luminous rays, while heat rays may act through the clothing.

Finally, it had been noted that men who worked at a foundry where metals were smelted by electricity, suffered very severely from the effects of the light upon their skin and eyes; that this was due to the action of the ultra-violet rays alone, and not to heat rays was proved by Widmark.

As far back as 1859, Charcot had expressed the opinion that it was the chemical rays and not the heat rays which are active in the cases of erythema solare, and that the dermatitis caused by a very strong electric light was identical with erythema solare. But it was not until 1889 that Widmark gave the scientific proof that such was the case.

Widmark caused the rays of an electric arc of twelve thousand candle power to pass through a layer of water thick enough to absorb the heat rays. Under the influence of this light, which contained all the rays except the heat rays, the skin subjected to it developed the characteristic inflammation; but when the light was passed through a plate of ordinary glass, which excludes the ultra-violet rays, the skin subjected to its influence was unaffected.

Having thus considered the phenomena of light apparent to the unaided eye, reported upon by other observers, and having studied the particular form of inflammation that was caused by a special irritant, Finsen wished to find out what the microscope could teach him about the changes produced, and whether the inflammation was a simple one, or complex in character. And so, early in 1893 he carried out some experiments upon tadpoles. Wrapping their bodies in filter paper kept moist and cool by cold water, thus keeping them alive and at the same time excluding any effects of heat, he placed them upon the stage of the microscope, exposed to the rays of the sun. After ten to fifteen minutes the capillary vessels were dilated, the circulation of the blood slowed, then ceased, leucocytes and red corpuscles escaped through the walls of the capillaries, as in simple inflammation, and the red corpuscles contracted, becoming compressed and more round. This demonstrated that light had a direct action upon the smaller blood vessels (capillaries) and also upon the blood itself; others had shown that light could cause the

contraction of living protoplasm, and its general influence on the system, especially through the optic nerves, needed no confirmation.

Nature's defence against this injurious action of the chemical rays being pigmentation, the manner in which the pigment was laid down should lead to the discovery of the very part of the skin requiring protection. In man, the pigment is placed in the deeper layers of the epidermis; there are no capillaries in the epidermis, but there are in the layer of skin immediately below it. In animals pigment cells are more scattered and often met with along the vessels of the skin. In reptiles complete tubes of pigment are seen around the vessels. From all of which it would appear that the blood vessels and the blood need protection.

As to the absorption of light; it might be permitted to reason from a law in physics that only the light absorbed by bodies could act on these bodies, the chemical influence of light being in direct proportion to the light absorbed. Applying this law to the animal organism it is found that no living tissue absorbs so much light as the blood does, and, more than that, it absorbs a considerable quantity of the violet rays.

Besides all the foregoing conclusions, other experiments showed him that light had a considerable influence upon the nervous system, at least in the lower animals.

Having thus summed up his theoretical and practical evidence as to the irritant character of the chemical rays of light upon the healthy body, he reiterates the fact that his researches do not exclude the beneficial action of the chemical rays when in moderation, but regard the harmful action as due to exposure to too great a number of the rays, and for too long a time.

Attention was then directed to acute diseases of the skin which might be produced by the chemical rays, and next to those diseases of the skin, which while not due to the chemical rays were unfavorably influenced by them. If chemical rays could produce a severe inflammation upon healthy skin it was most natural that they should exert an injurious influence upon a diseased skin.

While deep in these researches and experiments, Finsen found in the library of the University of Copenhagen some articles bearing on the unfavorable action of light upon the course of small-pox. One of these was by Picton of New Orleans and published in 1832; it merely mentioned the fact that some soldiers confined in dark dungeons during a certain epidemic of small-pox, had contracted the disease and recovered without suppuration or scarring, but did not attempt to offer an explanation of the phenomenon. In 1867 and 1871 the English physicians, Black,

Barlow and Waters had published articles noting the action of light upon small-pox, but little attention had ever been paid to them. With Finsen it was different; he solved the mystery. His interpretation was that theoretically these observations agreed with the fact that the face and hands, the parts most exposed to light, were the seats of the deepest scars, and those most prone to merge into one another.

In his own words; "I saw clearly that the chemical rays would play an important part in this, and that is why I proposed in July, 1893, to treat patients suffering from small-pox in rooms from which the chemical rays had been excluded by filtering the light through thick red curtains. At the same time I showed the theoretical principle of the treatment, which had hitherto been wanting, and soon afterwards the method was tried." His proposed treatment was based upon theory only, but an opportunity to put this theory to a practical test soon presented.

There was much small-pox in Bergen, Norway, at the time, and Dr. Lindholm, chief physician of the military service, and his assistant, Dr. Svendsen, made the first trial, but two months after the publication of Finsen's proposition, namely, in August, 1893. Eight patients were subjected to the red light treatment, that is light from which the chemical rays had been filtered by red materials, four being unvaccinated children, and bad cases. The result was that the most painful and most dangerous stage of the disease, the stage of suppuration, did not appear, the temperature of the patients did not rise, there was no swelling, and the horrible pitting did not occur. A very marked contrast to the results of former methods, and a justification of Finsen's theory.

These happy results were repeated by other physicians in various parts of the world, and in those cases where failure was reported, it was usually found to be the old story of the "just as good" plan. Either some essential detail was omitted, or treatment was commenced too late to be of avail.

Finsen also pointed out that where any preceding method to avoid scarring in small-pox had achieved a measure of success, it had been through the very principle for which he contended, namely, the exclusion of light from access to the skin, but used without actual knowledge of the rationale. Thus, the face had been painted with tincture of iodine which turned the skin red, or with lunar caustic which turned it black, both efficient filters of the irritating rays. Or the face had been covered with a mask coated or soaked with various fatty substances, or many other things, the success of which depended upon the extent to which light had been excluded from the skin.

Even red had been used in days gone by in the treatment of small-pox. "John of Gaddesden, who wrote the famous medical treatise, the earliest in the English language, 'Rosa Medicinæ,' and who died in 1361, treated the son of King Edward I. for small-pox by covering him with scarlet blankets and a red counterpane, placing him in a room in a bed with scarlet hangings, gargling his throat with mulberry wine, and having him suck the juice of red pomegranates, and the patient recovered, never showing any trace of small-pox." * * * "Also back in the time of Queen Elizabeth, the value of red curtains, red coverlets and red glass about the bed in small-pox cases was loudly proclaimed by certain doctors, who were regarded, as was John of Gaddesden, as charlatans by the orthodox physicians of the day." (Cleaves', "Light Energy.") So there were red bed-covers, and red globes in the bed for small-pox in the middle ages. Children were clothed in scarlet cloth, or kept in beds with scarlet curtains early in the 18th century in France, and the same custom prevailed in Japan. In Roumania, a custom from time immemorial is to cover the patient with red cloth, thinking that this attracts the eruption to the surface, and prevents complications. In Tonkin, the patient is placed in a sort of alcove, from which all light is excluded by numerous red hangings, and in a number of other diseases the same procedure is carried out; the custom is of great antiquity.

Finsen's plan involved absolute exclusion of the chemical rays, "small-pox patients must be protected from the chemical rays with as much care as the photographer uses for his plates and paper." A candle was permissible for artificial light while examining the patient, and while he was at his meals, but no brilliant illuminant was to be used. Treatment must be started as soon as possible after the rash appears, there is less hope after suppuration is established. Treatment must be continued until the vesicles have dried up. Even a short exposure to daylight would nullify the treatment. It was not claimed that death would always be prevented, but that if taken in time and all rules strictly carried out, suppuration would generally not occur, the patients would recover without scars, or only with almost invisible ones.

Four years later, 1898, Finsen published an Appendix to his paper on small-pox, setting forth the subsequent good results of many observers, still further confirming his plan.

Had Finsen contributed nothing more to the sum of human knowledge, he had well merited the gratitude of the entire civilized world, and his name would ever have been honoured on the roll of science, not alone for what he had actually accomplished, but even more for the new avenues of research opened up by his incessant labours. But great as

was this triumph, a still greater was to be the reward of his unassuming genius.

In 1895 he published a paper which has been as a light in the darkness to many an afflicted, hopeless, despairing sufferer, a revelation of many a mystery in life's mystic volume, an interpretation of many a dream of the plodding, patient investigator, an inspiration and incentive to all his co-workers in this most alluring of scientific fields, the dawn of a brighter day.

Hitherto he has dwelt upon and conclusively proved the irritant properties of light in certain conditions and under certain circumstances, and shown us how this knowledge may be put to practical use in a negative manner, by avoidance. But, as there are always two sides to every question, both of which may be right, so, on this great question of light, he throws fresh light, and bids us look on the other side of the picture and behold light in a happier mood, "Light as a Stimulant." In this contribution, as in the former, one cannot fail to be struck by the humble character of the experiments, contrasting so strangely with the value of the results obtained thereby. But as the skilled conjurer performs his most wonderful feats with the most homely, insignificant objects at hand, so to the true scientist, often a veritable latter-day wizard, no object in nature is too humble to wrest its precious secrets from, and score his greatest victories, and lay the world in triumph at his feet.

And so with Finsen; in observing the development of the eggs of the frog, he noted that movements of the embryo were considerably increased by the influence of direct sunlight, and that with the eggs of the salamander (Triton cristatus) the movements were still more marked. This set him thinking. By using coloured glasses, and occasional shading with the hand to imitate darkness, he found that the embryos responded more to some colours than to others. All sorts of precautions were taken to avoid mistakes, the exact period of exposure to each coloured ray was noted, and the exact number of movements, the water in the dish containing the eggs was kept cool to avoid errors due to the possible effects of heat rays. The result of the experiments proved conclusively that light provoked movement in the embryos, and that this must be attributed especially to the violet rays.

Next, attention was turned to salamanders an hour old, and others a day and a night old. Placing them in a dish of water, their natural element, and placing the dish in the shade, but where a beam of light could be reflected upon them by a mirror, it was found that under the influence of light they darted ahead, but otherwise remained motionless. Placing the dish half in the light and half in the shade, the salamanders moved

about excitedly until they reached the shady portion, when they became motionless again. Red, yellow, and green rays did not affect them, blue light alone provoked as rapid action as compound light. In this case the exact time in seconds which elapsed before movement occurred after exposure to the coloured light was carefully noted, likewise the possible effects of higher or lower temperature of the water. The great value of these experiments, as pointed out by Finsen, lay in the fact that salamanders of this age rarely move at all, without a violent external cause. The strength of light used, and the quality of the glass as to the rays which would pass through certain shades were carefully noted also. The latter is a factor frequently neglected by experimenters; the glass in this case was examined spectroscopically, in order to be positive.

When tadpoles were kept in the shade for some weeks, it was noted that they became very lively when exposed to daylight when the water was changed. Another interesting point was noted; a number of tadpoles had been raised from eggs which had been kept under light of different colours, but all received daylight every twenty-four hours, when the water of the aquarium was changed, at which time those raised in red light became very excited because unaccustomed to light, while those raised under blue light were quite indolent.

The experiments with the earthworms, placing them in an oblong box, with a lid of glasses, red, yellow, green, and blue, were repeated and varied by turning the cover after the worms had gathered at the dark end, thus exposing them to different strengths of light, but always with the same result, namely, the worms were uncomfortable in and avoided the blue light and sought the red. Some worms that were kept for feeding the salamanders met with an accident, some died and some were very weak; to save as many as possible various expedients were resorted to, such as moistening them, but without result. On exposure to direct sunlight, three or four began to react and recovered.

Experiments with the earwig (forficula) in the box with the glass cover quickly showed their desire to avoid the blue light. Thus, "when on turning the cover, the blue light fell upon the animals, their extraordinary evolutions were curious to watch. Their antennæ began to vibrate, the animals at once became restless, running to all sides, until they finally came to rest under the red glass. The experiments were frequently repeated, and at last the adults seemed to understand the situation, for after several changes of the light, they no longer mistook the road, but made off without hesitation towards the red light." Woodlice (oniscus) and beetles (pterostichus) placed in the box behaved as did the earwigs.

These animals are among those which dislike light, because of the excitation of the chemical rays; but how about those which like it?

To elucidate this point eleven butterflies (pieris) were placed in a large oblong box, half covered with red glass, and half with blue, and exposed to direct sunshine. At first, all beat their wings violently, but soon those under the red glass were mostly quiet, but those under the blue moved incessantly. "Later, when the sun ceased, the butterflies influenced by the blue light became quiet, and an hour afterwards they were disposed in such a manner that ten butterflies were in the blue zone and only one in the red." Inverting the cover, "at the end of an hour eight butterflies were found bathed in the blue light and three remained in the red." The experiments seemed to indicate the preference of these insects for the chemical rays, and the influence of these radiations upon their movements. Experiments with twenty or thirty meat flies (Musca vomitoria) did not give such positive results, ascribed to the great number and the variety of their motives of movement. But towards evening they collected behind the red glass and slept behind it, very rarely one remained under the blue glass and some under the orange. Placing sugar behind the blue glass did not attract them to sleep there. On placing opaque plates before the blue glass, rendering that end of the box the darkest, and illumining the red end, all the flies but one were found in the dark part, showing that flies like to sleep in places where the excitation of light is most feeble.

The conclusion drawn from these researches is that the action of the chemical rays (blue-violet) on these animals, compared with that of the heat rays (red), and light rays (yellow) is very considerable. It likewise demonstrates the extreme influence of the chemical rays upon the organism, which may broadly be defined as an excitation of the nervous system, which is so pronounced that it may provoke well-marked reflex actions (in the embryo), and in other instances produce very powerful and special reactions (in light-shunning and blanched animals) and it can truly be said that these chemical rays are promoters of life and energy. This action is constant and of daily occurrence and must be of great importance in the carrying on of the vital functions. Rays charged with such energy when absorbed by the body must have this energy transformed in many ways, the most marked transformation seeming to be this excitation of the nervous sytem, which, no doubt, influences in a secondary manner all the vital functions.

If the chemical rays possess such an influence over inferior animals, why not over man? And so unhesitatingly Finsen says: "I believe implicitly that in the future use will be made of this new therapeutic agent,

and the proof experiment once made, it will be easy to carry it out practically under the form of light baths; and lastly to determine whether they are to be blue or violet, the variations in their strength and duration, and whether natural or artificial." In this connection Finsen noted that light baths had been used in antiquity, and that General Pleasonton had used blue light to cultivate v nes and other plants, for rearing animals, and as baths for the sick; not however pure blue, for every blue square there were three clear ones. His book was published in Philadelphia in 1877, under the title of "The Influence of the Blue Ray of the Sunlight and of the Blue Color of the Sky in Developing Animal and Vegetable Life, in Arresting Disease, and in Restoring Health in Acute and Chronic Disorders to Human and Domestic Animals." He had concluded that since the sky was blue this colour must be of great importance to an mals and plants, and he also discussed the remarkable chemical qualities of the blue rays. Finsen remarks of him: "He thus approached the truth; but his faulty experiments, and, above all, his tendency to look upon blue light as a universal panacea—the very title of his book indicates this —have not contributed to show the value of a biological agent whose importance is beyond discussion. The General's book, printed on blue paper and bound in blue, makes one think, however favorably disposed one might be, that its contents could hardly fail to be 'coloured' also."

As a final argument on behalf of light Finsen cites the special effects of direct sunlight upon all organisms. "Sudden transitions from a cloudy to a clear sky make us feel it much more than continuous sun. If the sky has been overcast for part of a day, and the sun suddenly comes out, it is as if nature has been brought to life. The insects fly and hum gaily; the reptiles bask in the bright sunlight; the birds chirp; and we ourselves get a feeling of well-being and of fulness of life. This somewhat indefinable effect is none the less very marked. One might say that light is an 'exciter of life,' in the sense that it excites living activity and promotes movement. I believe I am right in saying that this quality has hitherto been attributed to the 'psychical' action of light and to that of heat. It seems to me that both my positive and negative experiments have sufficiently shown that we ought to refer the greater part to the chemical rays, which possess a stimulating influence on the lower animals."

This later work which we have been considering deals with researches carried on in the spring and summer of 1894, and published in February, 1895, and is only a mere fragment of a series of observations which he was conducting, but being interrupted, was unable to continue. In 1899 he published an Appendix to this paper, in which he detailed experiments carried out in the spring of 1895, in which he observed strong secondary effects of light upon the embryos of the frog wh:ch seemed to supplement

his former results, and besides, stamped the ultra-violet rays as the essential exciting cause of the action.

The experiments were carried out with great care and many precautions, in bright sunshine at mid-day, just as the embryos were emerging from the eggs. They were exposed to various colored lights, also to clear light and to shade, for stated times, and the movements carefully noted and counted, and showed that movements in the shade increased proportionally to the repetition of the experiment. Then they were allowed to rest in the shade undisturbed for several hours, when their movements were again counted. Suspecting some error, the experiment was carried out in another form. Three embryos being placed in the same flat dish used throughout, and being in the shade for five minutes, during which time only one movement was noted, were exposed to direct sunlight for five minutes, and then removed to the shade, and kept there for the remaining observations. During an exposure of five minutes to direct sunlight 45 movements were counted; during five succeeding minutes in the shade 107 movements were counted; during the next five minutes, still in the shade 112; then 75, 30, 32, 29, 22, 28. This experiment is quoted thus fully to illustrate how simple may be researches, fraught with immense potentialities, provided the observer possess the genius of interpretation, It meant that the effect of the chemical rays was only evident after a certain time, and might even attain its maximum after exposure to them had ceased, and, finally, suggested opportunities for new researches.

In this same paper Finsen alludes to another matter. Recalling his former suggestion of utilizing the chemical rays as a method of medical treatment of disease by light baths of the whole body, he draws attention to the fact that some charlatans, wishing to trade upon the reputation achieved by his researches, were employing incandescent electric light baths, pretending that they were based upon his work, and likewise using his name in a manner most distasteful to himself. Therefore he is impelled to remind the medical profession that the influence of light as a germ killer, and its power to cause inflammation and pigmentation of the skin, as well as its stimulating action, are dependent upon the chemical rays, and the light from incandescent electric lamps contains much less chemical rays than ordinary diffuse daylight, and that such baths acted by reason only of the heat rays given off by the lamps, and are simply of use to promote perspiration.

Proper light baths, on the contrary, are cold, and cause a marked effect upon the skin. His recent researches proved that the dilatation of the capillaries and bloodvessels of the skin produced by the light is not

merely temporary, but of long duration, and by causing a dilatation of the vessels and a more active blood supply, better nutrition of the skin is promoted, and greater functional activity. In Finsen's sunlight baths, the patients walk naked about a courtyard; to avoid the production of perspiration, water is frequently sprinkled about or douched over the patients. In the electric light bath, the room is divided by radiating partitions, and the patients lie naked upon couches. In the middle of the room, about six feet from the floor, a couple of large arc lights of 100 amperes are suspended. The temperature of the room is kept so low that artificial heat is necessary to prevent chilling of the patients.

But Finsen's greatest victory was yet to be won. Not content with the debt he had laid the world under already, he must invade yet another stronghold of disease, and conquer.

There is a disease quite common in some climes, not so frequent in our highly favored land which has so much to be thankful for, but present even here; a disease which was formerly thought to be cancer, and was called by the laity "wolf-cancer," but now is ascribed to the presence in the skin of the same germ (bacillus tuberculosis) which causes consumption when attacking the lungs or other parts. It is not called cancer any more by those who know, but its old name sticks to it, and it is called "wolf" just the same; Lupus Vulgaris, common lupus, the Latin term for wolf. It well deserves its name, for it is a cruel, gnawing, wolfish thing, rarely conquered, except at the cost of great scars. Attacking chiefly the face; sometimes the nose, or the lip, or the cheek; going on, sparing nothing, gnawing away, rarely killing directly, but leaving behind such disfigurement often, that death would be a glad relief indeed. "Hideous mutilation may be produced, destruction of the eyes, contraction of the mouth."*

But Finsen has been thinking as he wrought, and has caught a glimpse of a ray of hope, and bids the whole world rejoice with him and share anew in the glad pæan of praise that has been reverberating down through the countless ages since "the morning stars sang together," the praise of light.

In 1897 Finsen gave to the world his epoch-making paper entitled, "The Treatment of Lupus Vulgaris by Concentrated Chemical Rays," a form of treatment he had been putting to a practical test for two years, ever since 1895. In it he starts off by noting that the powerful germ-killing influence of light is now well recognized, hence, theoretically everything is in favour of its use in superficial skin diseases caused by germs, but its use for this purpose has been practically neglected. Some had

* Jacobi-Pringle, "Dermachromes."

already used light for the treatment of lupus, but it was either the heat rays of the focussing glass, or if light rays were used they were in too weak form to be of value. And so he determined to take up the s udy of this question from the beginning, as he seems to have done with every subject he investigated. And, as this germ-killing action of light is slow, it is necessary to concentrate it by mirrors or lenses, taking care to exclude the heat rays, the ultra-red, red, orange, and yellow, wh'ch would destroy the tissue by combustion, while the more easily diverted rays above them are the more active germ-killers.

Be'ore constructing any apparatus to put to practical use his many discoveries, he first made sure that the germ-killing action of light actually did increase :n proportion as the rays were concentrated. To do this, he coated the insides of two flat bottles with gelatine peptone, a material used for the cultivation of germs, and this soil he sowed with cultures of germs in pure bouillon (Bacillus prodigiosus which causes the red mould on bread, and Anthrax bacillus). Outside the bottles he gummed paper black on one side, white on the other; the white side out to avoid absorption of heat rays, the black side next the glass to prevent the light affecting the cultures where so protected from it. Several round openings were cut in the papers, and across the openings were traced on the glass in Indian ink numbers, indicating in minutes how long each opening was exposed to light. From one to two hours after sowing the germs, the flasks were exposed at the same time, one to direct sunlight, the other to concentrated sunlight. They were then kept from one to two days in darkness to allow the cultures to develop, in which time the results were very apparent, for "the numbers indicating the space of time in which the light had killed the bacilli were clearly marked on the culture by the colonies which had developed in the shelter of the parts colored black. In this manner the bacteria themselves indicated the time of exposure necessary to kill them." By many similar experiments he proved that sunlight concentrated by means of his apparatus killed microbes fifteen times more rapidly than direct light, and that the effects of the concentrated arc-light are very much more intense.

As light penetrates all tissues, even the bones, and as oxygen is necessary to enable light to kill germs, and as blood contains more oxygen than any other constituent of the body, Finsen first thought that the more blood there was in the part to be treated by light, the better it would be. But he soon found out his mistake and tells us of it. Placing a piece of photographic paper (papier ariosto) behind the lobe of his wife's ear, he allowed a cone of blue-violet light from his solar apparatus to fall upon the opposite side of the ear. At the end of five minutes there was no change in the paper, but on repeating the experiment while pressing the

blood out of the lobe by means of a piece of glass on each side of it, the paper was blackened in twenty seconds. So that blood has a very great deal to do with preventing the penetration of the chemical rays. Therefore he devised glasses of different shapes to press the blood out of parts while being treated.

He was now ready to try this plan of treatment by concentrated chemical rays in different germ diseases of the skin, and especially in lupus vulgaris, which he considered presented especially favorable conditions, for it is caused by the tubercle bacillus, is local, is frequently superficial, and light can kill the Bacillus tuberculosis, and not only kill the germ, but also excite and stimulate nutrition and excite activity in granulation, thus assisting recovery.

FIG. 1—Finsen's Original Solar Apparatus.

The method of treatment varied somewhat according to the severity of the disease, and the tolerance of the tissues to the action of light. An area of from one to three centimetres in diameter was subjected to the concentrated chemical rays daily, for several days or several weeks as the case might be. The treatments lasted at least two hours at first, later, with improved apparatus, one hour. When one spot seemed to have been sufficiently treated, another was attacked until the whole affected area had been gone over. Then, if any suspicious spots were left, they were attacked. Patients were examined occasionally after some months, and treated, if necessary, until no further spots were to be found. Each patient had a nurse who kept the spot in range of the rays, and saw that the rays fell perpendicularly upon the pressure glass. The immediate effect of the treatment was to cause inflammation of the skin (erythema) which was sometimes quite severe, depending upon the intensity of the light and also on idiosyncrasy; sometimes there was swelling of the parts, sometimes blistering, and crusting over.

When the parts had been sufficiently treated, the raised edges became flat, the redness disappeared, the parts became natural in appearance, and if there was ulceration it healed over. Scars were quite insignificant. The effect of the treatment continued for some time after the treatment was stopped, sometimes for several months.

The first apparatus used was one for concentrating sunlight, it consisted of a hollow plano-convex converging lens, 20 to 40 centimetres in diameter, filled with water colored blue by methylene blue or an ammoniacal solution of sulphate of copper, to exclude most of the heat rays. Later, the coloring matter was omitted as excluding too many useful rays. Blue cut out most of the ultra-violet rays, while clear water absorbs the ultra-red rays largely, and it is chiefly the latter rays which cause the heat. Through this simple apparatus mounted on a forked stand, which could be raised or lowered, the rays of the sun were focussed upon the diseased area, the patients sitting in chairs, or lying on tables out in the open air.

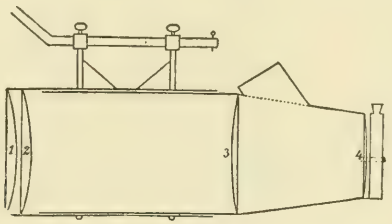


FIG. 2—Diagram of Finsen's Original Arc Light Apparatus, showing large glass lenses and heat filter.

But, as the sun's rays were not always available, the voltaic arc was utilized, the rays of which being divergent, unlike the parallel rays of the sun, required a different contrivance somewhat like a telescope, consisting of two cylinders, each containing two plano-convex lenses. Two close together at the outer end of the outside tube, and having their plane surfaces towards the source of light, to cause the divergent rays to become parallel; the two other lenses so arranged as to make the parallel rays become convergent into a cone, which is allowed to fall on the part under treatment, but not at the focus but a little in front of it. Between the two latter lenses there was a layer of distilled water, and outside at the end next the patient a light filter of blue solution, which was later discarded. The intensity of the arc light used varied from 35 to 50 amperes. The apparatus was suspended from the ceiling of the room, and to economize the electric current, four tubes were placed about the arc-light at an angle of 45 degrees, so that four patients could be treated at the same time from one lamp.

During 1897 Finsen made several improvements in his apparatus;

he used an arc-light of 80 amperes, and had his lenses constructed of rock crystal, (quartz) which allows the ultra-violet rays, which are absorbed by ordinary glass, to pass; the power of these rays to destroy germs being much greater than that of the visible chemical rays. The effect of these improvements was to increase the curative effect, as well as the rapidity of treatment. With it he was able to kill the bacillus prodigiosus in one minute, and a lupus the size of a pea disappeared completely after a fifteen to twenty minute exposure. Unfortunately, rock crystal lenses are expensive and can only be obtained of small dimensions.* Further improvements in the apparatus consisted in placing an additional cooling chamber surrounding the lower portion of the tube; and also the distilled water chamber between the lenses. By means of inlet and outlet tubes connected by rubber tubing to a source of water supply, the cold water thereby kept circulating in the chamber kept the distilled water between

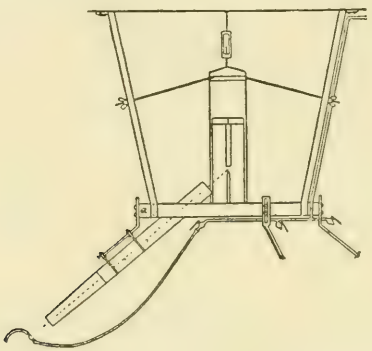


FIG. 3—Diagram showing Improved Tube, its relation to the arc and cooling device of pressure lens.

the lenses cool, otherwise it became boiling hot. But in spite of this extra cooling device the light was still too hot for the patient, so Finsen devised a hollow compressor, consisting of a plate of rock crystal (quartz), and a plano-convex lens of rock crystal, set in a conical ring, leaving a space between; an inlet and an outlet tube in the ring permitted a constant supply of cold water; by means of arms projecting from the ring, the compressor could be either firmly fastened on, or held by the attendant nurse. The pressure exerted upon the part, driving the blood out of it and thereby permitting better penetration of the chemical rays, which passed more readily through the crystal and contained water than through the former glass.

Finsen recognized that the method was capable of much improvement, the greatest drawbacks being the length of time occupied by each

* "Quartz is very prone to break along its line of crystallization and the cutter never knows when this accident may befall. The author has been informed that as much as a ton of quartz was used befor a perfect single focal lens of quartz two inches in diameter was obtained." Cleaves' "Light Energy."

treatment, the time necessary to effect a cure, and the expense of the apparatus.

Finsen's first patient for treatment by the concentrated chemical rays, had been trying for eight years since the lupus had appeared, various forms of treatment without avail; the side of his face had been operated on twenty-five times; had been cut, scraped, burned with acids and with hot irons. In the autumn of 1895 Finsen began to put his theory to the test. The apparatus used was of the simplest description; the rays from an ordinary electric arc light were converged upon the diseased side of the face daily for one or two hours, by means of a hand lens, a reading magnifying glass, the heat rays being filtered out by passing through blue solution in a glass capsule. In six months the patient was cured, and the irritant chemical ray, so harmful where small-pox is concerned, was proved a stimulant, and a positive curative agent in lupus vulgaris.

Finsen saw at once the possibilities of light cure in this and similar conditions, but recognized that in order to carry on the treatment properly, expensive apparatus was necessary, and a suitable place for patients

FIG. 4—Pressure Lens of Rock Crystal with cooling device.

undergoing treatment. All this required money and he was a poor man. At first, of course, there was much scepticism manifested, as this disease had hitherto proved so refractory to all manner of treatment. But soon two wealthy Danes, Mr. G. A. Hagemann and Mr. Vilh. Jorgensen came to his aid with financial assistance, and largely through their generosity the Light Institute was founded in Copenhagan, in April, 1896. The Commune Hospital of Copenhagen, the municipal hospital, gave space in its gardens for several small buildings, and in these Finsen's experiments went on, in more extensive form. Such good work was done at the Institute, that the Danish Government came to its support, the State granted a loan free of interest, and on August 12th, 1901, the Institute was removed to Rosenvaenget, a pleasant suburb of Copenhagen, and was also considerably enlarged, being comfortably housed in a handsome stone building with large airy and bright rooms, and provision for treating two hundred patients daily. It contains laboratories and a clinic for the carrying out of phototherapy, and particularly for the treatment of lupus and other diseases of the skin by concentrated chemical light. The program of the Institute is, "To make and support scientific research con-

cerning the action of light upon living organisms, and especially to apply the results to the service of practical medicine." Finsen fully recognized that his discoveries, important as they were, could only be regarded as a first step, not as a finality.

It is said that in the first six months of its existence, only ten or twelve cases came to the Lys institut, and one nurse sufficed, but since its establishment, over two thousand patients, coming from all parts of the world have been treated, with a record of about 98 per cent. of cures; there are now six doctors on its staff, and it employs about sixty nurses. The work done there is chronicled in a special publication in Danish and German. McClure has a capital description of the way work goes on at the Institute written by Cleveland Moffett, and I cannot do better than give you his charming word picture in full.

"Suppose we look in now at Finsen's Light Institute and observe something of its practical working. One is struck first of all at the beauty of the place, set in the midst of lovely gardens, shaded by fine trees, and walled about with vines and flowers. No cheerless hospital this, but a handsome villa in the choicest part of Copenhagen. Here are the laboratories and Finsen's home, and just adjoining, a long white two-storey building where patients are treated; all this a gift of the Danish Government. As you glance through the hedges, you see a glow of red light like a foundry and figures moving behind wide-open doors. These are the lupus patients, and the glare is that of the red-shaded Finsen lamps, for each lamp has the intensity of thirty-five thousand candles, and there are seven in one large room.

"The seven lamps with their glowing red curtains are seven centres of cheerfulness, and under each one you are surpired to see laughing, chattering groups, eight people to a lamp, four patients and four nurses. The patients lie comfortably on high cots and receive the light from four down-slanting tubes like telescopes, in which are the costly rock-crystal lenses and the water for eliminating the heat rays. These tubes the nurses move into position so as to focus an intense concentrated beam, yet sufficiently cool, upon the surface under treatment, usually some part of the face, and they also press the surface with a water-filled glass which serves the double purpose of freeing the tissues from blood and still further cooling the rays. That is about all there is to the treatment, which goes on thus in seances of an hour and a quarter a day for each patient, and, being quite painless, leads naturally to pleasant sociability in the various groups.

"In moving about the room one sees patients of all ages, from four to seventy, and more women than men. They come from different countries

and speak various languages. Several are from England, attracted by the small cost of treatment, only sixty kroner a month (about eighteen dollars) for the very poor, or 100 kroner for those in better circumstances. Fancy being cured of lupus, actually cured, for a dollar a day: Here is a German girl busy with her sewing while she waits her turn at the lamp. She was meant to be pretty. Here is a man with his collar off, taking the treatment fast asleep, as often happens. And watch the nurses, very neat in their gray and white frocks, as they bend over their charges. Red spectacles guard their eyes against the dazzle, their arms are bared to the elbows, their hands are busy with the light, and on their faces is a glow which is partly an up-reflection of the rays and partly an outward reflection of kind thoughts, for there is a peculiar dignity and sweetness in these Danish women.

"So the seance drowses along with a low buzz of talk and the regular clicking of the lamps as the clockwork feeds down the carbons. Sundays and week days alike throughout the year, the light cure is in operation, and has been now since 1896, in which time the actinic rays have shown abundantly what they can do in destroying the bacteria of lupus. Not in a few weeks, it is true, but surely, after such time as is required—sometimes months, occasionally years when the disease is very bad. And it should be borne in mind that most of the cases received up to the present have been bad ones, lupus of twenty, thirty, or even forty years standing."*

The stimulating action of light is clearly manifested in another manner also at the Lys-institute, for "both patients and nurses in Finsen's clinic acquired a thicker growth of hair on those parts which were exposed repeatedly and for a long time to the powerful electric ray."†

The results claimed for the treatment of lupus vulgaris by concentrated chemical rays, about 98 per cent. of cures, is a truly wonderful record, when all the failures of the past are reviewed with all their hopelessness. And, so, many attempts have been made, and in many lands, to improve upon the original apparatus of Finsen; for the initial cost of the lamp, and the cost of its maintenance, and the cost of a special nurse for each patient, together with the length of time consumed for each treatment—one hour or more—and the prolonged period of treatment, several months, or perhaps years, have combined to render this form of treatment rather unpopular. It is quite impracticable to treat cases satisfactorily unless at a public institution, such as the one established by the great discoverer himself, or in a room specially arranged for the purpose and devoted to no other use. But, ingenious as many of the

* Cleveland Moffett, "Dr. Finsen and The Story of His Achievement." "McClure's Magazine." February, 1903.

† Freund, "Radio-Therapy"

substitute contrivances are, none of them can compare with the original lamp of Finsen. Many of them give out rays very rich in the ultra-violet light, some much richer than the original lamp, and capable of killing germs comparatively near the surface in very much less time; but these more rapid germ-killers labour under the universal disadvantage that their rays do not penetrate so deeply as those of the original Finsen lamp, which gives out rays of much lower rate of vibration than they do, although deficient in the upper ultra-violet rays as compared with them.

The result of all this most meritorious striving for better things has been not only the exercise of much ingenuity, but also the attraction of much earnest thought in the direction of light and light-treatment, that else had trended otherwhere. In many styles of substitute lamp, the great aim has been to bring the source of light energy closer to the part to be treated, also to have fewer lenses intervening, hoping thereby to husband many of the active rays that would otherwise be absorbed in the lenses and the intervening space. Again, others have incorporated different metals with the carbons which go to form the arc; and others have substituted iron or other metals for one or both carbon electrodes, thereby effecting a marked saving in the amount of electricity consumed,

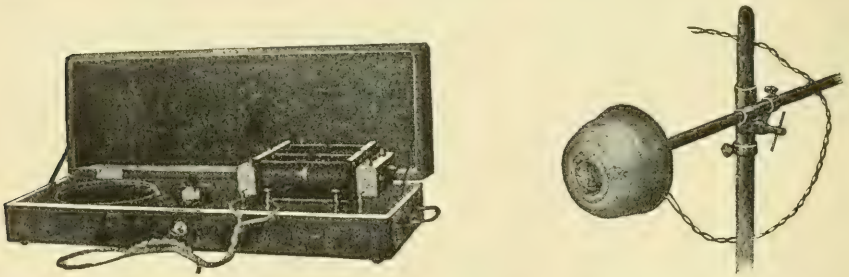


FIG. 5—The "Ultra," with iron electrodes, one of the many outcomes of the Finsen Light.

and increasing notably the proportion of ultra-violet rays given out, the vapour of the burning iron giving a spectrum very rich in the wished-for bactericidal ultra-violet. But these while gaining in ultra-violet, have lost proportionately in the less refrangible, more penetrating rays of lower frequency, and this fact miltates against, or even prohibits their successful use in deep seated affections. Were lupus confined to the surface of the skin alone, the victory would lie with the "improved" apparatus.

But, in spite of all that has been done, the original Finsen lamp, with such modifications as have been introduced by the originator of this treatment himself, remains to-day the only reliable means of carrying out his light treatment in the more severe and deeper seated cases.

And yet, wonderful is the law of compensation; all this ingenuity

is not lost, for the advent of the smaller and cheaper instruments has opened up a far wider field for treatment than would fall to the lot of the Finsen light proper, in diseases due to germs, parasites and fungi, and not so deeply seated as is lupus. Indeed, many of the apparently hopeless cases of lupus itself are amenable to the iron electrode arc rays, even after twenty-five years' standing.

Finsen's assistants have played no small role in the development of the minor instruments of iron arc and others, for, being thoroughly unselfish, he encouraged all who were trying to improve on his methods.

Then, another thing happened. In the quest for a substitute for the time consuming lamp, the x-rays were tried, and it is an undoubted and chronicled fact, that the first successful use of the x-ray as a curative agent, was in the treatment of the same disease, lupus vulgaris, in which the light treatment was so successful. This is more than a mere coincidence. And it is interesting to note that the only hitherto successful claimant to the honour of being able to cure this horrible disease in its worst forms is the x-ray. And, to-day, the very best treatment consists in the careful discriminating use of these two agents as the main features; anything else of value is merely secondary. Which is one more debt we owe Finsen.

And the vast fields opened up, not merely in diseases of a purely local nature, but in those of a general character also, add fresh lustre to this already most brilliant reputation, and attest anew how deep and how full of hidden riches were the caverns of knowledge he explored, and how unfailing and far reaching was his greed for light, and to know what it was and what it could do. He planted, and we are only beginning to reap the harvest, and to realize in a very small measure how well he wrought and how much we owe to him.

It was but natural that such a self-sacrificing student of nature and her wondrous hidden ways should attract to him kindred spirits, warmed by his enthusiasm, cheered by his counsel, encouraged by his example, fired with his ambition to know all, letting nothing escape their keen scrutiny, and alike with him exact with exceeding exactness. And such indeed was the case.

It was his privilege and in part his reward, to surround himself with many such, and the results of their combined labours merit naught but unstinted praise for the accuracy of their observations, and the clear manner in which they have elucidated many a problem otherwise obscure, and for their exactitude in chronicling the time in which the different sources and varieties of energy produced certain effects, establishing

thereby a standard of dosage, as it were, for particular cases, according to the source of energy.

What did the world of science think of Finsen while he was still alive? Let us hear the testimony of the most widely accepted continental authority on light-therapy, Dr. Leopold Freund of Vienna. After chroncling a long list of honored names of those who had also labored in this most alluring field, and setting forth all that they had accomplished, he says; "None, however, has done such work for the furtherance of light-therapy as Finsen (from 1893 onwards). He first made careful experiments of his own, and tested thoroughly those of others, and then, having laid a sound theoretic basis, he constructed the apparatus by which he was able to prove the usefulness of light when applied in its most intense form to malignant growths such as lupus."* Like praise is accorded by one who has done by far the most valuable work on this continent in light-energy, Dr. Margaret A. Cleaves of New York. In her recent splendid volume, "Light Energy," alluding to the fact that precisely similar apparatus had long been used for experimental purposes, Professor Freund having cited that in the Vienna Institute for Practical Pathology. Dr. Cleaves goes on to say: "All of which is illustrative of the fact that the means to the attainment of a definite end in all matters of scientific development lie at our door awaiting the interpretation of and application by the intuitive intelligence. Such is the order of the genius possessed by Finsen, and having proved by his experimental work the action of light he was at once able to supply the needed apparatus for the utilization of the intense chemical frequencies of light energies from an electric arc." "It is not necessary to corroborate Finsen's work in lupus vulgaris by that of any other. It stands unparalleled and needs neither proof nor disproof."

It was Finsen's rare privilege to be appreciated by his confreres and the public ere he passed away. And that was another great reward. Paintings of merit acquire more value as they grow older and after the artist's death; and a man's life work usually requires the perspective of time before its true worth is acknowledged; but it seems as though Finsen in upsetting many theories with regard to light, likewise upset this utterly wretched theory with regard to life—which is so akin to light—and was the recipient of sincere and unstinted praise and honour from most varied and unaccustomed quarters, during his all too brief existence.

The Royal family of Denmark became deeply interested in his work very early, and in this manner Her Majesty, Queen Alexandra, then Princess of Wales, and her sister, the Dowager Empress of Russia, while

* Freund "Radio-Therapy."

on their customary yearly visit to their father, King Christian in Copenhagen, investigated the work at the Lys-institut for themselves and saw there what was being done, and were so much impressed with the results that were being obtained, that on returning to their respective countries they took steps to have the whole matter looked into by independent observers of highest repute. And so, in 1898, the Prince of Oldenburg was sent from St. Petersburg to Copenhagen by the Empress of Russia, and was accompanied by three very eminent physicians to study the methods of Finsen. On their return, they had a most favorable report to give, and, as a result, a light institute was opened in St. Petersburg.

Nor was the Princess of Wales less impressed, or less active in this praiseworthy mission of help for the helpless, for in a private visit in July, 1899, to London Hospital in Whitechapel, the poor man's hospital in the poor man's district, the Princess enquired at great length as to the treatment carried out with regard to lupus cases, and informed the rather incredulous surgeons that a compatriot of her own had discovered a cure, and that she had personally seen results of the treatment at Copenhagen, offering at the same time to present a Finsen lamp to the Hospital, which generous offer was gladly accepted and arrangements made for the installation of the apparatus, and on May 29th, 1900, the lamp was ready for service. Meanwhile the senior physician of the hospital, Dr. Stephen Mackenzie and Dr. Sequeira set off for Copenhagen to study the treatment; two nurses were also sent to be trained in the methods, Her Highness doing everything possible to make their visit pleasant.

As soon as treatment was commenced at the London Hospital a tremendous number of patients presented themselves, and a second lamp was soon added. But even this did not suffice to accommodate all the sufferers. Each lamp was of thirty thousand candle power and could be utilized on four patients at once. The cost of working one of these four tube lamps amounted to about $3,000 per year; this added greatly to the burden already borne by this great charity. The wonderful work that was being done came to the notice of Sir Alfred Harmsworth, and he and Mrs. Harmsworth decided to endow one of the lamps in perpetuity. Soon after this Mr. Percy Tarbutt raised a sum sufficient to endow the second lamp, namely, $50,000. Other lamps have recently been added, together with some improved and smaller ones, so that at present twelve patients can be treated at once, each requiring a nurse.

The good example of royalty was followed soon, and lamps were installed at Charing Cross and Westminster Hospitals, Liverpool, Manchester, Royal Hospital in Dublin, and elsewhere in Great Britain. But even with all this provision, the capacity of the lamps is overtaxed at all times and the "waiting list" is lamentably long.

Chiefly through the influence of the Queen of Greece a Light Institute was opened at Athens, and among other places where treatment by light is now carried on may be mentioned Hamburg, Cologne, Munich, Vienna, Buda-Pesth, Paris, Cairo, New York, Baltimore, Washington, Chicago and Toronto.

Crowned heads seemed to vie with one another in their homage to this remarkable man. On the occasion of his last visit to Copenhagen not only did His Majesty King Edward and Queen Alexandra visit the Light Institute but called on Professor Finsen at his home afterwards. The Emperor of Germany when in Copenhagen a little over a year ago, was also a visitor to the Institute, and before leaving it said to the Crown Prince, "See that you erect a monument to Finsen during his lifetime." But the Lys-institut is Finsen's best monument. It is also related that the Dowager Empress of Russia, calling upon Finsen and finding that he was too ill to be seen, pleaded with his devoted wife to be allowed to see him, and on being admitted to his study, wept bitterly in sympathy with his suffering. And incidents like these might be multiplied almost indefinitely, all going to show the keen personal friendship that existed between this brave, uncomplaining invalid, and all the members of the Danish Royal Family.

What like was this man, who seemed to draw with irresistable magnetism, all who were privileged to come within the influence of his charm? What of the man himself? for we have dealt merely with his work. In answer it may be said that his work was his life. One writer has said of him that his "life was almost wholly the life of a mind; he had few physical capacities left him. All the physical strength he possessed merely entailed for him so much power to endure physical suffering. That is the great fact which makes his life marvellous; and see how much work, and what wonderful work, his courage enabled him to get through."*

Let us go back a bit, not far, for he died young. Forty-five years ago the world had not known Niels Finsen, and the whole world was just that much poorer, for many a hopeless lupus sufferer died utterly unaided in his loathsome disfigurement. But now, from the altar of a life of almost endless pain and suffering there ascendeth, and shall ever ascend the sweet incense of hope and health for the sick and weary. Of him it may truly be said, "He gave his life for the sick."

Niels Ryberg Finsen was born on December 15th, 1860, on the Island of Stromo, at Thorshavn, the capital and chief town of the Faroe Islands, which lie between Iceland and the Shetlands, and belong to Denmark.

* "The Spectator," London Oct. 1, 1904.

His father was domain judge, and was descended from an old Icelandic family, hence some of Finsen's early years were passed at school in Reykjavic, the capital of Iceland, where he remained until his twenty-first year, passing his student examinations there. He then entered the University of Copenhagen in Denmark, at which he remained for eight years, graduating as Doctor of Medicine in 1890 at the age of thirty. As a student, he lived in the famous old Copenhagen Home for Students, the Regensen, the *Collegium regium*, built by Christian IV.

It is related of him that even as a young student he evinced that love of true freedom which became such a characteristic feature in the man. "It was at the time when the policy of the Estrum Government roused the ire and the wrath of its opponents to a degree rarely seen in Denmark. In some places the peasantry refused to pay their taxes, thereby incurring certain personal inconveniences, for which their sympathisers tried to recompense them by hailing them as a kind of martyrs. Some of these men had come to Copenhagen, and Finsen and his *Contubernal* (the student who shared his room), thought the Regensen ought to honour these champions of the good cause in some way. They knew, however, that the master of the College, the "Regensprovst"—dean—as he is called, was distinctly adverse to this kind of demonstration, but his permission was necessary, so they innocently asked his leave to entertain a few friends from the country, and it was readily given. The next day the worthy dean was much surprised at seeing paragraphs in the papers about a party of "Shattenägtere" (tax refusers) having been entertained at the Regensen with his, the dean's permission. Finsen naturally was jubilant."*

It is said that from the standpoint of examinations, (a most fallacious standard often) he was only moderately successful as a student, graduating in the second class. This was perhaps largely due to his attention having been already directed very specially to the influence of light upon living organisms; ascribed to the observation that he was able to work better in the well-lighted room of a fellow-student than in his own.† He knew that he felt less well when, for a time, he occupied a room facing the north.‡ Wihle yet a student he had begun those investigations and experiments that were destined to make him famous, and at the same time his inventive genius found scope in devising an improved breech-loading gun, cool summer houses, a new cooking apparatus, and later a variety of hæmatine lozenges. The investigations started in a small attic of the old Surgical College building. Sophus Bang, a fellow-student, believed with him that a complete revolution in therapeutics was necessary. Both became ill, and while Bang went to Switzerland to strive to regain health,

* Bröchner "Pall Mall Magazine."
† "Lancet." London. ‡ "Pall Mall."

and is now one of the foremost anatomists of Europe, Finsen stayed in Copenhagen to conduct his researches in its foggy and cold atmosphere.

For the first three years after his graduation, up to 1893, as has already been said, Finsen had to content himself with the humble post of prosector in anatomy to his University; but with the publication of his first paper on the action of light upon small-pox he became famous, and after 1893 he was relieved of the necessity of teaching, and enabled to devote all his attention and energy when health permitted to his investigations in the nature and properties of light, and its applications to the treatment of various diseases. Wealth and a life of ease had no charms for him, he declined to make money out of his discoveries, or to patent any part of his apparatus, and was well-content with his modest salary from the Danish Government of $1,200 a year.*

The result of his self-sacrifice we have already seen. A fellow-countryman of his, Jacob A. Riis, says of him as he met him in 1899, while recovering from a fever: "I would sit in his little office down in the corner of the hospital grounds by the lake and watch the patients who had come in pain and gloom, go away, carrying in their faces the sunshine which had given them back their life. And I came to look with a kind of reverential awe upon this patient, silent man, whose every thought was for his suffering fellows, while he calmly counted the hours to his own relief from racking pain. I learned from his own lips the story of his great temptation; how when he found what he sought he lay awake one whole long night, debating with himself whether to turn it to account in private practice—Finsen is a poor man—or to give it and his life to the world. He chose poverty, and the world is the richer for his sacrifice; how much we can hardly realize under our brighter American skies, where the disease with the ravening name (*lupus*—a wolf) is comparatively rare." . . "Cradled in the island of storms and wintry night, he loved the sun. His eye lighted up when he spoke of it: 'Let it break through suddenly on a cloudy day.' he said, 'and see the change. Insects that were drowsy wake up and take wing; lizards and snakes come out to sun themselves; the birds burst into song. We ourselves feel as if a burden were lifted. In our daily life we give to the sunlight the place that belongs to it, without question. The housewife "suns" her clothes. We shun dark rooms, especially bedrooms.' . . With the spirit of the true investigator he went back to nature and considered the ant and the lizard, and their ways."†

Another writer, Cleveland Moffett, says of him! "It is fitting that a

* Moffett, "McClure."

† Jacob A. Riis, "A Word About The Man," ("McClure's Magazine")

great discovery touching the treatment and cure of certain diseases *by light alone* should be given the world by a man who lived in Iceland until he was twenty-one, and knew through all his boyhood the depressing influence of too much night." One of the first things Finsen said to him when he went to see him in Copenhagen was this, and he said it with touching humility: "All that I have accomplished in my experiments with light and all that I have learned about its therapeutic value has come because I *needed* the light so much myself. I longed for it so."*

A writer in *The Spectator* already quoted draws our attention to the fact that, "He was only twenty-three when he found that his heart and liver were hopelessly diseased, and, as if that were not enough to crush his desire to work, he was attacked by dropsy. He was, it is said, actually 'tapped' to relieve the dropsy more than thirty times. He had to realize, and realized with sheer bravery, that he could only keep himself alive by the strictest and most rigid discipline of diet. Every ounce of food and drink that he took was weighed,—for twenty years. Possibly in that time he lost—just possibly he never possessed—the desire to live naturally and joyously as most men live; but even if he never possessed such a desire—and there are some men who do not possess it—he as a student of medicine and biology, was always intimate with the possibilities and capabilities of a man's body; and the amazing keenness of his intellect must have brought home to him a poignant sense of loss which a blunter mind perhaps, would not have been able to realize. Yet he determined to live, not in the hope that life might bring him eventually freedom or partial relief from physical disability and grinding pain, but simply because, however painful life might be, the fact of being alive meant the ability to think."

This man who knew the very depths of suffering, would laugh at pain that would have rendered helpless many another. He even studied the diseases which he knew were to kill him some day; watched their progress; wrote articles on them for the medical papers, and on one occasion remarked with a humorous gleam in his eyes that he much regretted his inability to be present at his own post-mortem examination. A few weeks before the end, he sent a paper to the London *Lancet*, in which he maintained his unshaken confidence in the therapeutic value of the red light treatment of small-pox, stating that some who had recently had unfavorable results had not given the method a fair trial, in that all their patients were placed under treatment too late. This paper was published in November, 1904, after his death.

Finsen's home life was a very happy one, in spite of suffering. His

* "McClure's Magazine."

wife was a daughter of the aged Bishop Balsley, and helped him very faithfully in his great work, and he was a devoted husband and father. He had three children, the eldest about nine years old and the youngest about two. He was a staunch friend; his intense devotion to his favorite pursuit, his constant struggle against his physical disabilities, with such rare courage, his unusual modesty, and his total absence of self-seeking endeared him to all who came in contact with him.

When the Nobel prize in medicine was awarded to him by the Norwegian Parliament in December 1903, he said laughingly, "They gave it to me this year because next year would have been too late." He seemed to actually dislike money, perhaps as a friend of his has said, because he wished his son to be able to say in the words of the charming Danish poet, Holge Drachmann, "I thank thee, my father, thou wert not a wealthy man."* And so when the prize came, he at once wished to hand the whole amount, 100,000 crowns (about £8,000) over to his beloved Lys-institut, and it was only with the greatest difficulty that his friends were able to persuade him to allow one-half the amount to be placed at interest for the benefit of his family, the remainder going to the Institute to carry on the work he initiated. But his old friends M. Hagemann and M. Jorgensen comforted him immediately by presenting the Institute with an additional 100,000 crowns.

Finsen was very fond of music, but did not play any instrument himself; he was also much interested in art, and used to paint a little when too ill to go on with his researches.

His devotion to his work was so intense that his friends despaired constantly; he scarcely took time to sleep or eat, and his death was doubtless hastened by overwork aggravating the diseases from which he had suffered since manhood.

The Copenhagen *Daily Vort Land* paid this tribute! "According to ordinary human reckoning, Finsen's life was too short, yet he was given time to accomplish great things and to prepare the way for his followers. The universal judgment of him will sound like a universal thanksgiving—thanks from the land whose honored son he was, thanks from the scientific world for which he opened up new avenues of achievement, thanks from the unfortunates from whom he lifted the heavy burdens of disease.

"Himself an invalid since early youth, his first and last thoughts and desires were to aid others. What he has accomplished has been indorsed by all civilized countries, and more than twenty great sanatoriums in as many cities throughout the world stand today as lasting monuments

* Bröcher. "Pall Mall Magazine."

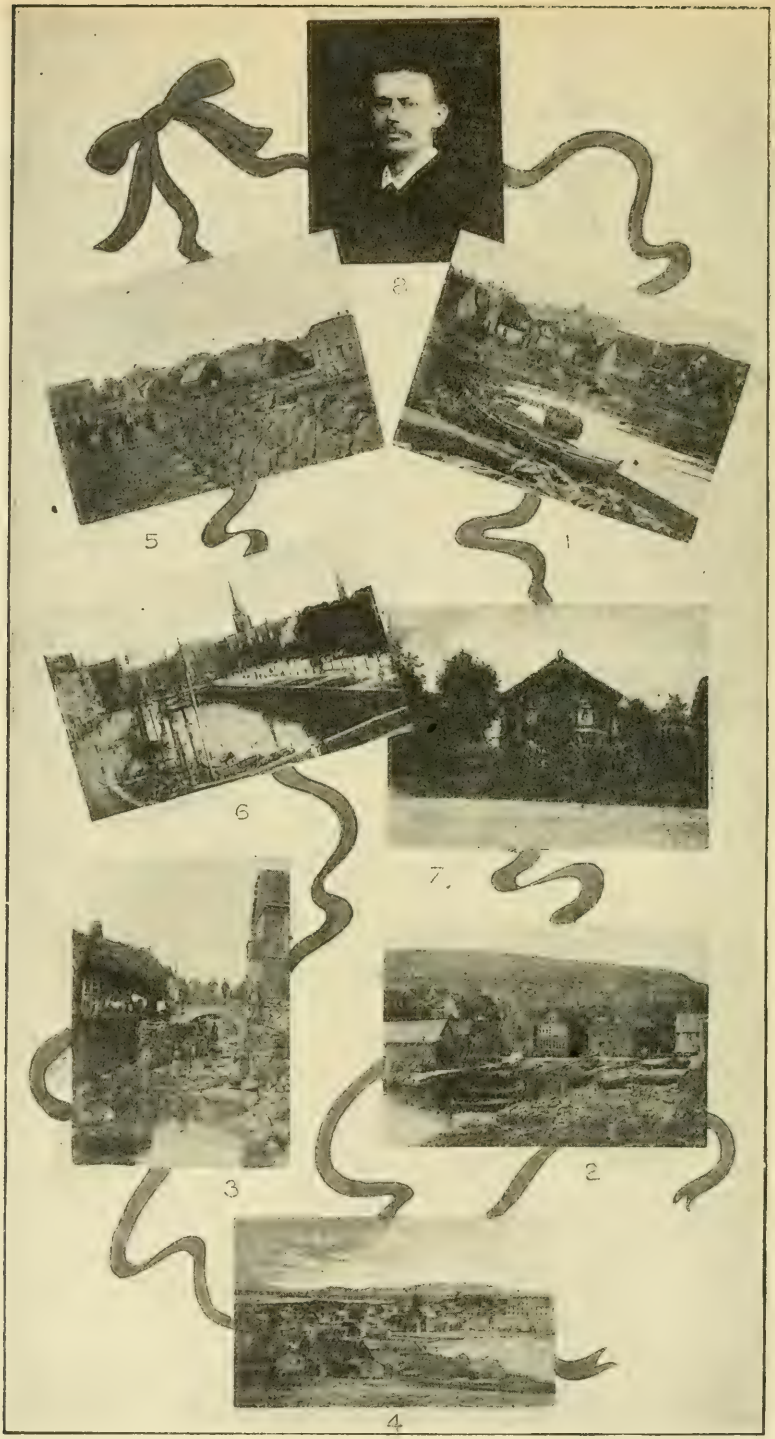
to his fame But he who did so much for others was himself a sufferer from a disease which baffled medical men. A few days before his death he requested his physicians and friends to perform an autopsy on his body in order that, even in death, he might serve his profession. The dissection revealed the fact that he had been suffering from slow ossification of the heart membrane, a rare disease, which generally results fatally after a much shorter period than it did in Finsen's case. His remarkable will-power no doubt prolonged his life for several years; he simply *could not* leave the labour he loved."*

And so, on Saturday, September 24th, 1904, the "wolf-slayer" went home to rest at last.

Copenhagen mourned as completely as when six years before her beloved Queen Louise died. The whole two miles of the procession was lined with respectful, silent crowds. The ceremony took place in the Marble Church. The services were attended by King Christian of Denmark, King George of Greece, Her Majesty Queen Alexandra and the Princess Victoria, the Dowager Empress of Russia, the Crown Princess of Denmark, all the Royalties in Copenhagen at the time. Queen Alexandra brought a beautiful wreath, and King Edward sent another from England. A deep impression was made when some two hundred persons who had been cured of lupus by the late Professor, took their seats among the mourners.†

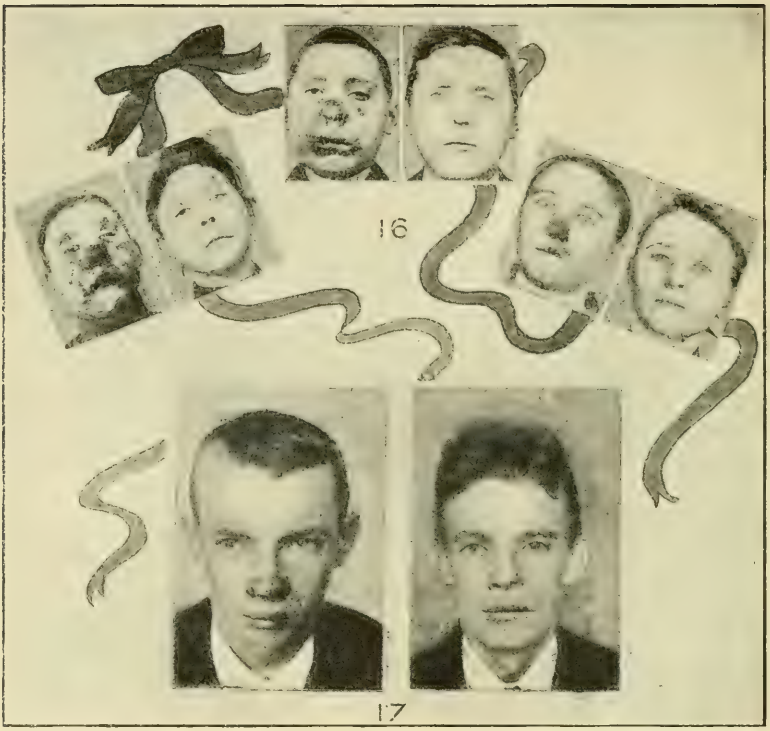
This paper cannot more appropriately be brought to a close than by quoting again from *The Spectator:* "One passage out of the many fine passages in which Robert Louis Stevenson has written of life and death, rises to the memory as a comment on the life of Professor Finsen. . . . 'It is better to lose health like a spendthrift than to waste it like a miser. It is better to live and be done with it, than to die daily in the sickroom. By all means begin your folio; even if the doctor does not give you a year, even if he hesitates about a month, make one brave push and see what can be accomplished in a week. It is not only in finished undertakings that we ought to honour useful labour. A spirit goes out of a man who means execution, which outlives the most untimely ending. All who have meant good work with their whole hearts, have done good work, although they may die before they have the time to sign it. Every heart that has beat strong and cheerfully has left a hopeful impulse behind it in the world, and bettered the traditions of mankind.'"

* Quoted in "Literary Digest."
† "The Graphic," Oct. 8, 1904



1. Thorshavn, Stromö, Capital of the Faröes, from the Harbour, Government House.
2. South Harbour, Fish Stores, etc.
3. The Stream through Thorshavn.
4. Reykjavik, Capital of Iceland.
5. Business Quarter of Reykjavik.
6. Copenhagen, Capital of Denmark.
7. Finsen's Home, Copenhagen.
8. Niels Ryberg Finsen, "The Wolf-Slayer." Born Dec. 15th, 1860, at Thorshavn, Stromö, Faröe Islands. Died Sept. 24th, 1904, at Copenhagen, Denmark.

9. Finsen ready for work. 10. Royalty at the new Lys-Institut at Rosenvaenget, Copenhagen. Main Room. Visit of Queen Alexandra, Dowager Empress of Russia, Crown Prince and Crown Princess of Denmark, April, 1903. 11. The first Finsen Lamp in England. Presented to London Hospital by Her Royal Highness Alexandra, Princess of Wales, completed May 29th, 1900. 12. The first large Finsen Lamp in America, at Chicago. 13. The original Arc Light Apparatus at the First Light Institute (showing the tubes with large glass lenses). 14. Treatment by Concentrated Sunlight at Copenhagen. 15. King Edward and Queen Alexandra at opening of new Finsen Light Room, London Hospital, June 11th, 1903.



16, 17. Cases of Lupus cured at Finsen's Lys-Institut, showing also increased growth of hair from effects of light stimulating the scalp.

18. The Funeral Procession leaving the Church. 19. King Christian of Denmark entering the Church.
20. The Lying-in-State.

THE GROWTH OF TRINIDAD.

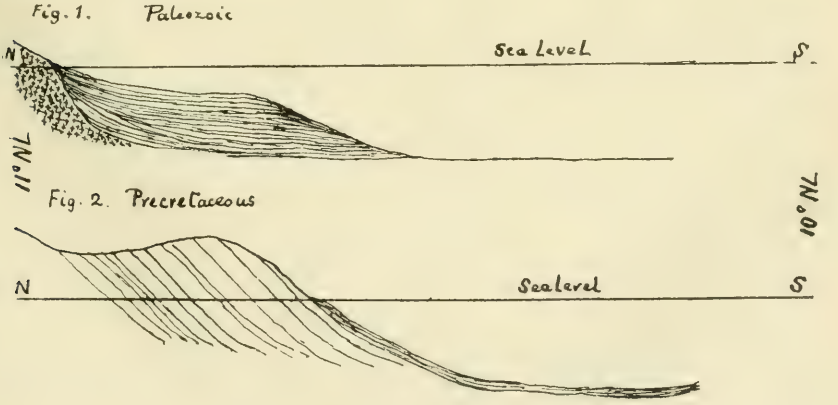
By R. J. Lechmere Guppy.

(*Read 25th March*, 1905.)

(Prefatory Note.)

(As there are many places named Trinidad it may be well to explain that the locality referred to in the following paper is an island off the north-eastern coast of Venezuela from which it is separated by the Gulf of Paria and the channels connecting that body of water with the main sea. It is situated between the parallels of 10° and 11° of north Latitude and mostly between the meridians of 61° and 62° west Longitude.)

Unlike the volcanic islands which lie contiguous to it on the north, Trinidad is in no part formed of ejections from the interior of the earth. Volcanic rocks do not exist here, and the only volcanic material that I am acquainted with, is the volcanic dust found in our oceanic deposits. The island is wholly formed of materials derived from the degradation of other land. It is the object of this paper to trace the course of development of the island, from the time when the first rocks of which it is composed were laid down under water.



The first foundations of the existing land were laid down as shore deposits and limestones, and these now form the hills of the northern or Parian Range; the oldest rocks of the island. These rocks therefore, are

of ancient geological date. They traverse the entire width of the island, from the Islet of Chacachacare, on the west, to the north-eastern promontory, called Punta Galera. The main ridge has an elevation of 1,600 to 2,500 feet. Several high peaks rise out of this ridge; the highest is said to be Tucuche, 3,000 feet, and the next, Aripo, 2,700 feet or more. Indeed it is probable as we have often surmised, that one or more of the Aripo summits exceed Tucuche in height.

Our first view therefore, (see the diagram Figure 1), of the nascent Trinidad, is of a series of deposits under water, originating in the operations of denudation upon an older land, the exact position of which is uncertain, but which for some reasons I surmise to have lain to the north-east, or in the direction of Tobago. That it was a large continent must be inferred from the fact of such an immense quantity of matter of such varying degrees of fineness and coarseness being deposited; probably many times the quantity we have now before us, as the quantity removed by denudation since the upheaval of the mass is obviously much more than what remains.

The next phase in the development of the island, was the upheaval of these deposits above the level of the sea, and their gradual uplifting until they formed the mountain-chain we now call the Parian Range, the southern boundary of a continental mass of land extending perhaps as far in latitude as 12° or 14° North. No facts are known whence to infer the extent in longitude of this continent. It may have extended far to the eastward, and perhaps have been continuous with that ancient land now submerged, whence the materials of the Parian Range (the "Caribean Group") were derived. The extent northward of the continent is partly shown by the remains of it still existing in the shape of rocks, banks, shoals and islets in the southern part of the Caribean Sea. The land thus indicated was probably continental in the cretaceo-eocene period, while in earlier times the continent probably extended much further north. The great depth of the Caribean Sea is the principal fact that stands in the way of our speculations here, and until we can see how to account for this, we must be content to leave much unexplained. The elevation of the oceanic rocks of Barbados from a depth of more than a thousand feet below sea level, to more than a thousand feet above it, helps us easily to explain the condition of the shallower parts of the Caribean Sea, but when we come to depths of 6,000 to 15,000 feet in latitude 12°-13° North, we feel that our present resources in the way of evidence are insufficient to support the hypothesis of an Antillean continent in Latitude 12°-15° North.

To the south of the Parian Range, the open ocean probably covered the whole of what is now the valleys of the Orinoko and the Amazons.

This phase of the development of the island is indicated in Fig. 2. How long as measured in years was the duration of these events, namely 1° the deposition under water of the rocks of the Caribean formation, and 2° their elevation to form the Parian Range, it is impossible in the present state of our knowledge to conjecture, but we may assume that it was a period measured by hundreds of thousands of years.

The assumption that after the elevation of the Caribean formation into the Parian Range it attained the height of more than five thousand feet above the sea is based firstly upon the fact that the series in Venezuela attains the height of nine thousand feet; and secondly, that since the elevation of that formation there have been extensive movements of depression which have greatly reduced the height attained by the Caribean formation in the Island of Trinidad. The evidence for this will be found in the sunken valleys and other geological phenomena which I will refer to in due course.

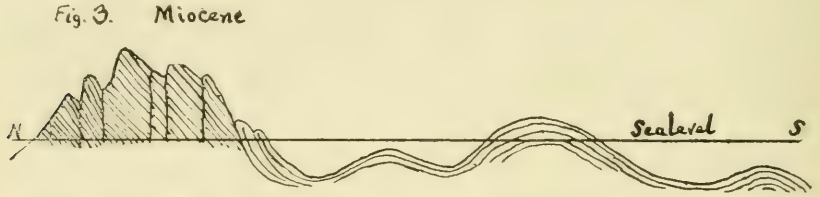
The Government Geologists (Messrs. Wall & Sawkins, the value of whose work becomes more obvious every day) estimated the thickness of these rocks (which they styled the "Caribean Group") at 10,000 to 12,000 feet. For my part I am inclined to think that here as in other parts of the island many strata shown as separate deposits are in reality, mere continuations one of another, thrown up or down by dislocations. But on the other hand the estimated thickness may not be less than that stated because in the first place great portions of the strata have been removed by denudation; and secondly, there are beds unseen which lie beneath those exposed to view.

As regards the composition of the rocks, I could not improve upon the description given in the Geological Report, (page 13). Clayslates, micaceous and talcose schists with quartzites, and crystalline and compact limestones, may be said to be generally characteristic of the formation.

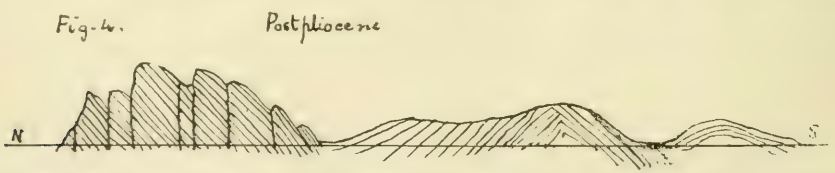
The compact limestones which in some places abut against the newest beds of the Caribean formation, are considerably later in date than that formation, and may possibly be Devonian or Carboniferous, while the Caribean Formation itself we have conjectured to be somewhere near the Silurian in age. The fossils hitherto found are insufficient to enable us to speak with any certainty on the point.

The strike of the rocks is in general terms coincident with the direction of the main range, that is from east to west, with a slight divergence to the north of east, and south of west. The watershed or dividing ridge of this Parian Range, is within a mile or two of the Caribean Sea, and approximately parallel to its shore, so that the valleys running to the northward are

small and short. With few exceptions the valleys run north and south or nearly at right angles to the general direction of the range. The valleys running to the southward are larger. Many of them are ditch-like and steep-sided in their lower or southern portions, while they have large lake-like expansions in their upper parts. This latter feature is indeed not less noticeable in those valleys which like Diegomartin, are broad and flat in their lower portions, than in those which, like Caura, are steep-sided, ditch-like ravines. This can be seen from an inspection of the map accompanying the Geological Report. I append a map showing this feature and also the dislocations which are the cause of it. I proceed to describe the phenomena.



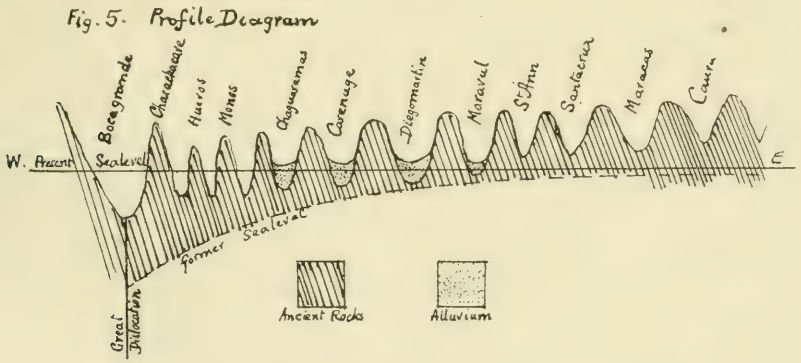
The dislocations indicated in the diagram-sections (Figs. 3 and 4), and in the map (Fig. 9) which traverse the range from west to east, no doubt took place at various times in the geological history of Trinidad. Which was the oldest of these dislocations is hard to determine but it may possibly have been the most southerly of them. This passes through Latinta Bay, Chacachacare, giving its direction to Chacachacare Harbour, a sunken valley formed along the line of that fault. This same fault passes north of Gaspari and Puntagorda, and continues its easterly course near the base of the southern slopes of the higher hills. The next great dislocation north of this, is marked by the saddle between Santacruz and Maraval, by the Maracas Waterfall and by several escarpments throughout the range. This is the dislocation which has had the principal share in producing the lake or basin-like expansions of the valleys in their upper parts described in this paper. Another line of dislocation is marked by Makarip Cove, and this also continues eastward through the range at a distance from one to two miles north of the one last mentioned. The northern



escarpment of Tucuche, among others, is due to this fault. Most, or more probably all, the east and west valleys which occur in the range are in one or another of these dislocations.

The next great fault is the one which divides the existing land of Trinidad from the formations which lie beneath the waves of the Caribean Sea. This lies somewhere near the line of the north coast.

That dislocation which had probably the greatest share in producing the existing physical features of Trinidad is one which appears to begin to the westward of the lagoon of Guarapiche in Venezuela, passing through the Gulf of Paria and the Bocagrande and extending to the north-eastward between Tobago and Barbados on the east, and Grenada, St. Vincent and St. Lucia on the west. It was this dislocation that brought about the separation of Trinidad from Venezuela, forming the Gulf of Paria, and depressing the western side of the island, so that the pluvial waters of the country now called Caroni, Couva, Naparima, etc., instead of flowing as they formerly did in an easterly direction, now flow westward. The alluvial and oceanic tertiary deposits now became subject as a consequence of the increased gradient towards the sea-level to a highly destructive erosive action which carried off great portions of the strata, reducing them to less than half their former height, and with the material thus carried off, filling up what would have been a chasm nearly one thousand feet deep, so that the main body of the Gulf is nowhere a hundred feet in depth.



The diagram Fig. 5 shows the result of this dislocation in altering the conformation of the valleys of the Parian Range as I have shown in another part of this paper. Beginning at the western end of the island the submerged valleys, not less than the Gulf of Paria itself, are plain evidences of this depression. These valleys are obviously produced by subaerial denudation, though now sunk below the sea-level. The bocas themselves had their origin as valleys through which flowed rivers from that ancient continent which formerly existed to the northward. These valleys after submergence have been greatly enlarged by the action of the sea, and the rapid currents flowing through them do not allow of the

deposition of any sediment in them; all loose material, whether eroded from the sides or transported by currents from elsewhere, being immediately carried away to deeper water outside. Not less clear is the testimony of the wide and comparatively shallow valleys of Carenage and Diegomartin, originally much deeper but now to a great extent filled up with alluvium. As we go eastward from Diegomartin, the valleys become steeper and narrower, assuming the form of mere ditches in their lower portions but having immense delta-like deposits of alluvium at their mouths ranging from 80 to 200 feet in height above the level of the Caroni Plain, which lies to the south all along the base of the northern or Parian Range.

Fig. 3 shows the condition of things in the miocene period after the Parian Range had been raised to its maximum height and when movements of depression had dislocated and faulted it. The miocene rocks were now in course of being laid down in the sea to the south of the Parian Range, while the eocene rocks had been partly uplifted. This state of things continued until the post-pliocene period, movements of depression taking place in the Parian Range, while elevation was going on in the middle and southern portions of the island, the result being as shown in Fig. 4, where the tertiary formations are seen elevated much above their present height leaving two valleys, one in the line of the present Caroni and Oropuch (N.E.) Rivers and the other in the line of the Pitch Lake and Oropuch (S.W.) Lagoon and Ortoir River. Through these valleys flowed rivers which had their origin in the mountain ranges of South America, and their outlets to the eastward of the present shore line of the east coast of the island. Up to this time Trinidad was not a separate land from Venezuela. When the Caribean formation rose above the level of the sea, the Parian Range was continuous with that of Venezuela, and the subsequent growth of the island by the deposition and upheaval of the cretaceous and tertiary beds was continuous likewise across what is now the Gulf of Paria.

In the valleys mentioned which are shown in the diagram, (Fig. 4), large estuarine formations were developed, and in these were deposited extensive layers of vegetable matter now converted into lignite, manjak and asphalt. But before this, and indeed during the whole time when the movements of elevation which raised the oceanic deposits from deep water were going on, there was a continual laying-down of fine clastic matter, accompanied by vegetable remains, all through the tertiary period.

The relationships of the various deposits, mostly of tertiary age, forming all that part of Trinidad south of Latitude 10° 40′ North, are extremely complicated. But by aid of the key given by the elucidation of the phenomena described in this paper, they will sooner or later be completely unravelled. No good exposure of the relations between the strata containing *Orbitoides Echinolampas* and *Terebratula*, and the oceanic beds

of Naparima has yet been found. I am of opinion therefore, that all that has been published, (and that of course chiefly by myself), is liable to large correction. Also the true sequence of the rocks at Pointapier has not been made out. The Ditrupabed will probably prove to be much later in age than the adjacent strata; and the study of its fossils leads me to believe it to be miocene and possibly late miocene, somewhere about the equivalent of the tertiary beds of Cumana in Venezuela.

The soils of the northern division of the island are derived from the degradation of the ancient rocks of the Parian Range, whose origin and formation I have described. The calcareous part is dissolved and carried away almost entirely by the running waters, some of which hold large quantities of lime, so that the gravelly and sandy detritus occupying the beds of valleys consists almost entirely of the siliceous constituents of the rocks. This gravelly and sandy detritus, though it affords a receptacle for water wherever there exists a barrier of any kind to prevent it from flowing off at once, does not, as clays and marls do, enter into intimate union with its contained water. Consequently where narrow passages admit of a slow escape of the water, the exhaustion of the reservoir down to the point at which it is tapped by the apertures of escape, will depend upon the proportion between the latter and the volume of water contained in the reservoir.

Before the great subsidence which separated Trinidad from Venezuela all the valleys and ravines running southward in the northern range had the same ditchlike character throughout that still characterizes the lower portions of the Caura and Aronca valleys. But on the occurrences of the dislocations already referred to and particularly that one passing along the axis of the Gulf of Paria and through the Bocagrande, as shown on the map (Fig. 9), the upper portions of those valleys were thrown down below the level of the lower portions. The thrown down upper portions became filled-up by gravelly alluvium derived from the waste of the surrounding ridges. I need hardly say that the subsidence was slow and that the basin-shaped expansions were never in the condition of lakes or even of swamps. Filling-up was always much in advance of subsidence. Nevertheless though not actually lakes these basin-shaped cavities became vast underground reservoirs of water which escapes slowly at their lower extremities. The perennial character of the streams of the northern part of the island is in a large measure due to the phenomena described. I will endeavour by the aid of diagrams to make the case more clear. The figures and descriptions given are not those of any particular valley but of a generalized or ideal valley illustrating the peculiar features common to most of the valleys under consideration.

Cross Section.—Fig. 6 is a diagrammatic section showing at one view the outline ABC of the lower valley or ravine while DEF is similarly the outline of the upper or thrown-down portion of the valley. This section is intended to represent the state of things upon the line of fault crossing the valley. The portion HEG of the upper valley is represented as filled with alluvium; while the portion KBL only of the lower valley is so filled. HKLG represents the surface of the valley bottom above the fault, while below the fault the width of the valley bottom is reduced to KL.

Fig. 6. Cross Section of Valley at Line of Fault

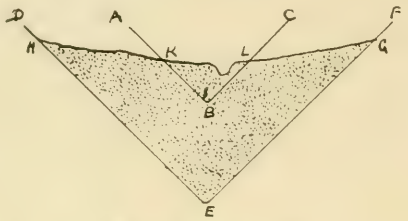


Fig. 7. Plan of Valley at Fault

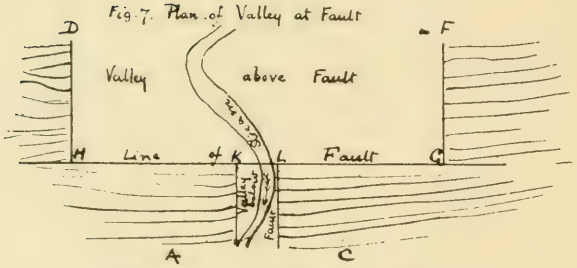
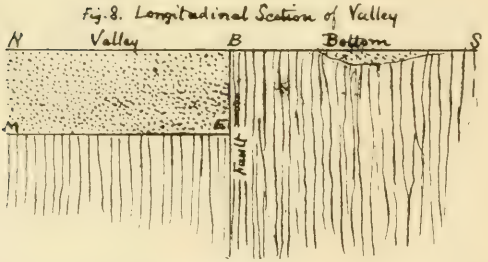


Fig. 8. Longitudinal Section of Valley



Plan.—Fig. 7 is a plan taken at the level of the bottom of a valley. It shows from a birds eye point of view the sudden reduction in the width of the valley at the line of fault indicated in the preceding diagram (Fig. 6) HG is the width of the valley bottom above the fault while KL is the width of the valley bottom below the fault.

Actually no such regularity obtains as is shown in these diagrams. Practically the reservoir is of extremely irregular figure and composition; the irregularities and the sinuosities of its outline all add to its storage

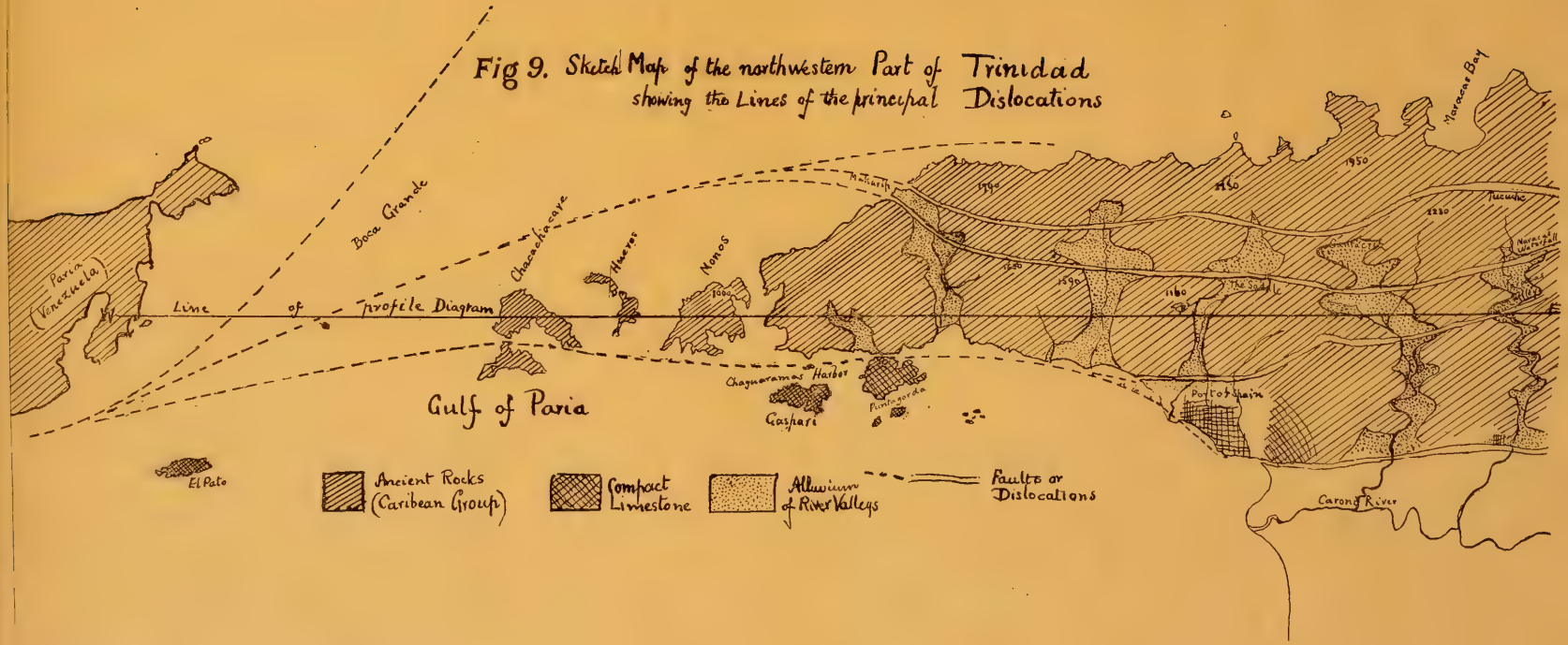


Fig 9. Sketch Map of the northwestern Part of Trinidad
showing the Lines of the principal Dislocations
Paria (Venezuela)
Boca Grande
Chacachacare
Huevos
Monos
Line of Profile Diagram
Gulf of Paria
Chaguaramas Harbor
Gaspars
Pointe-a-Pierre
Port of Spain
Maracas Bay
Mt. Hardy
1950
1550
1990
1630
1680
2220
Tucuche
The Saddle
Carong River
El Pato
Ancient Rocks (Caribean Group)
Compact Limestone
Alluvium of River Valleys
Faults or Dislocations

capacity and aid in rendering the outflow of water more regular and more gradual. From the main reservoir or that occupying the main valley there extend on every side into the hills accessory and subordinate reservoirs each of comparatively small capacity but forming in the aggregate a very large water-holding area, each part of which is so connected together as to part with its contained water slowly through channels and fissures, sometimes so narrow as to admit scarcely the blade of a knife.

Longitudinal Section.—Fig. 8 represents a section of the river-valley along its course and at right angles to the line of fault. NBS is the present level of the valley bottom, ME being the thrown-down upper portion. The area NBME is filled-up with alluvium, and is a part of the vast underground water reservoir before referred to. BE shows the extent of the downthrow along the line of fault.

Similar phenomenon to those now described occur no doubt in other parts of the world, but with one exception, I have not met with any account of them. They vary considerably from the ordinary form of water sources as described in the textbooks (*e.g.*, Geikie, Geology, page 344, Lyell, Principles, Vol. 1, page 391). The exception I have referred to is contained in a paper on the water basin of Loch Derg in Ireland, by G. H. Kinahan (Geological Magazine, London, 1873, page 286). There is however, this difference in the two cases, that in ours one fault produces depressions in each of the valleys it successively crosses while in the case of Loch Derg, a number of depressions are produced in one valley by successive faults.

The course of a fault or dislocation is often obscured by the effects of denudation and meteoric action, and where it crosses valleys it is covered with alluvium, so that it is not always possible to follow it with any certainty, but in other cases it is very evident by the broken ground, the escarpments or other natural features which mark its course often feet or yards wide. This is why faults are so apt to become valleys, the broken-up material occurring along the course of the fault being more easily removed by denudation than the solid unfractured rock, and the water having easier access. These facts are of course, familiar to every geologist, but it is as well to mention them here. In certain parts of the island, *e.g.*, Naparima, every valley (or at all events such as run east and west) is on the line of a fault. In the northern hills this is not so much the case as the principal valleys cross the lines of dislocation at right angles and only the subordinate (or east and west) valleys are situated in faults. Unless indeed, it should be hereafter found that any of the north and south valleys are in lines of fault; but of this there is no evidence; and it is

unlikely to be the case as those valleys follow lines of drainage which were traced out before the faultings and subsidences took place.

As regards the question why the dislocations and faults should be regarded as due to subsidence rather than to elevation, I think the evidence is pretty clear that the Parian Range was upheaved however gradually as one mass as represented in Fig. 2. The forms of the submerged valleys show that they originated as sub-aerial valleys, consequently subsidence must have taken place, and to this subsidence are due the faults and dislocations which occur throughout the formation.

SUMMARY.

The principal conclusions arrived at from a study of the geological phenomena exhibited in Trinidad are:—

1. The land of which Trinidad formerly formed part, originated from deposits laid down in the sea and derived from pre-existing land. When this operation was going on the whole area occupied by Trinidad was sea.

2. When the Parian Range rose above the waters it was the southern portion of a large continental mass of land whose extent we have not the means at hand to enable us to determine with any approach to exactitude. At this time the valleys of the Orinoko and Amazons were sea.

3. During the neozoic or cretaceo-tertiary period, the rocks now forming the southern portions of the island of Trinidad were deposited; and were raised above the level of the sea towards the close of that period. During that time there was no separation of Trinidad from South America, and the land surface was continuous. It is probable that simultaneously with the rise of this land surface, extensive dislocations and depressions took place in the Caribean area resulting finally in the separation of Trinidad from Venezuela, the formation of the Gulf of Paria, and the reduction by denudation of the newly-separated land to near its present level. The contemporaneous phenomena in other parts of the West Indies have been made the subject of discussion by J. W. Spencer, Gregory and others.

EXPLANATION OF THE DIAGRAMS.

Fig. 1 represents the nascent Parian Range. The Caribean formation is being deposited beneath the waters of the ocean.

Fig. 2 represents the land of the Parian Range elevated 2,500 feet above the sea-level. The strata are conformable and unfaulted, but tilted at an angle by upheaval. The elevation is supposed to have subsequently attained the height of at least 5,000 feet, perhaps much more.

Fig. 3 represents the period when the elevatory movements of the Parian continent had ceased and subsidence had given rise to extensive faults in the Caribean formation which is here represented as 4,000 feet high. Elevating movements had taken place to the south, raising the cretaceo-eocene deposits partly above the level of the sea.

Fig. 4 represents the island at its greatest elevation in the southern part, when it was considerably higher than at present. Depression and denudation have since operated to reduce its height.

Fig. 5 is a profile diagram from west to east along the Parian Range in the north-west part of Trinidad, showing how by the great subsidence passing along the axis of the Gulf of Paria that gulf and the bocas or mouths leading from the gulf into the Caribean Sea have been produced. The line of this profile is shown on the map Fig. 9.

Figs. 6. 7 and 8 are respectively a cross section plan and longitudinal section of a valley near a line of fault showing how the lake-shaped expansions of the upper portions of the valleys have been produced. These diagrams are fully described in the text.

Fig. 9 is a map of the north-western portion of Trinidad, showing the lines of the principal dislocations, the line of the profile diagram (Fig. 5), and the valleys with lake-shaped expansions in their upper parts. In this map the broken lines or leaders indicate the probable submarine courses of the principal dislocations. On the shaded parts representing land the approximate courses of these dislocations are shown by double lines.

NOTE.—The Diagrams accompanying this paper are not intended as exact delineations of the actual phenomena—such could only be obtained by minute and detailed survey. Though for the most part roughly drawn to scale they are intended to be diagrammatic only. So taken they are sufficiently accurate representations of the facts. It is of course understood that the vertical scale is very greatly exaggerated.

APPENDIX.

List of Works relating to the Geology of the Caribean Area.

NOTE.—A brief indication of the subject of each work is given and not the title. This List is by no means intended as an exhaustive bibliography. Some few papers of minor importance have not been noticed; and there are some works which I have seen but to which I have not access at present and so am not able to include them. But I believe that very little of importance in the history of Caribean geology has been omitted. I have found such a list as this absolutely necessary for my studies in West Indian geology. With a few exceptions all the books and papers mentioned are in my own library.

R. J. LECHMERE GUPPY.

1819. NUGENT, Antigua. Trans. Geol. Soc., Lond., Vol. V.
1839. VONBUCH, Petrifactions rec. par Humboldt.
18... HOVAY, Antigua. Am. Journ. Sc., Vol. XXXV.
1842. *ORBIGNY, Fossiles de Columbie. Inst. de France.
1850. MOORE, Sandomingan Fossils. Journ. Geol. Soc., Vol. VI.
1851. *BAYLE & COQUAND, Foss. du Chili.
1853. HENEKEN, Sandomingo. Journ. Geol. Soc., Vol. IX.
1858. *KARSTEN, Kreidebildung von Colombia.
1859. DUCHASSAING, Formations de Guadelupe.
1860. WALL, Venezuela and Trinidad, Journ. Geol. Soc., Vol. XVI.
1860. WALL & SAWKINS. Geology of Trinidad.
1863. DUNCAN, West Indian Fossil Corals, Journ. Geol. Soc., Vol. XIX.
1863. SAWKINS, Jamaican Granite, Ibidem.
1863. GUPPY, Older Parian in Trinidad, Geologist, pp. 204 and 363.
1863. MOORE, Jamaican Fossils, Journ. Geol. Soc., Vol. XIX.
1864. GUPPY, Fossil Foraminifera, Geologist p. 159.
1865. GUPPY, Late Tertiaries Trinidad, Geol. Mag., Vol. II.
1865. DUNCAN & WALL, Jamaica, Jour., Geol. Soc., Vol. XXI.
1866. GUPPY, Jamaican Fossils, Journ. Geol. Soc., Vol. XXII.
1866. GUPPY, Tertiary Formations of W.I., Journ. Geol. Soc., Vol. XXII.
1867. GUPPY, West Indian Geology and Atlantis, Geol. Mag., Vol. IV.
1868. DUNCAN, Fossil Corals of W. I., Journ. Geol. Soc., Vol. XXIV.
1869. BARRET & WALL. Geology of Jamaica.
1869. *TATE, Guiana, Journ. Geol. Soc., Lond., Vol. XXV.
1869. *FOSTER, Caratal Goldfield, Journ. Geol. Soc., Vol. XXV.
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THE CHEMICAL INDUSTRIES OF THE DOMINION.

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PREFACE.

MUCH of this paper appeared about two years ago in the *Journal of the Society of Chemical Industry*.* Recently it was communicated by request to the Canadian Institute after having been revised and, in a measure, brought up to date. A closer scrutiny of the subject matter, however, led to the conclusion that entire revisal and rewriting were necessary in order that it might present the condition of the chemical industries of the Dominion as they are at the time of publication. Every effort has been made to do this as far as possible, and the writer hopes that any shortcomings will be brought to his notice.

In writing on such a subject as the Chemical Industries of Canada, two main considerations have been kept in mind; firstly, that the development of the industrial resources of the Dominion during the past decade has been phenomenal, and secondly, that the extent of these developments is only fully understood by a few. While it is impossible to discuss *all* the industries in which chemical operations and reactions are made use of, an attempt has been made to select processes in some cases peculiar to the country, but notably the industries which owe their development to the natural mineral and vegetable resources, and to the widely scattered water power obtainable in the Dominion.

The subjects taken up may be classified as follows:—

I.—Common Salt and Alkali.
II.—The Extraction and Refining of Metals.
III.—The Manufacture of Leather.
IV—Sulphuric Acid, Acetic Acid, Wood Alcohol, Charcoal, and Ammonia
V.—Soap and Glycerine.
VI.—Refined Chemicals and Drugs.
VII.—Fertilizers.

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* Journal of the Society of Chemical Industry, May 15th, 1903

VIII.—Coal-Tar and Asphalt.
IX.—Calcium Carbide, Carborundum, Corundum and Graphite.
X.—The Cement and Plaster Industry.
XI.—The Beet-Sugar Industry.
XII.—Natural Gas and Petroleum.
XIII.—Pulp and Paper.
XIV.—Asbestos and Mica

I.—COMMON SALT, ALKALI AND CHLORINE COMPOUNDS.

Sodium chloride is found in the upper silurian beds in Ontario, and in the Devonian in Manitoba and Athabasca; salt springs also occur in Cape Breton and in New Brunswick, but these are comparatively unimportant sources of supply. In Ontario the salt area stretches through the counties of Middlesex, Huron, Bruce, and Lambton, large deposits being found along the shore of Lake Huron from Kincardine to Windsor. At Goderich there is a deposit 126 feet thick, and at Windsor a well extending to a depth of 1,672 feet passes through four beds of rock salt of an aggregate thickness of 392 feet.[1] The salt is obtained by evaporation, and is of an excellent quality. The following comparison serves to illustrate the purity of the natural product.[2]

	Natural Salt of Goderich, Ontario.	Natural Salt of Cheshire, (England.)
	Per Cent.	Per Cent.
Sodium chloride	99.687	96.70
Calcium chloride	0.032	0.68
Magnesium Chloride	0.095	0.00
Calcium sulphate	0.090	0.25
Moisture	0.079	0.63
Insoluble matter	0.017	1.74
	100.000	100.000
Total Impurities	0.234	2.67

The total production of salt in Canada was valued in 1892 at $162,000, in 1901 at $262,328, and in 1903 at $334,000.[3 *bis.*]

Apart from its use as a seasoning and as a preservative, common salt is employed in the electrolytic preparation of caustic soda and bleaching compounds.

The alkali and bleaching powder industries throughout the world

(1) W. Hodgson Ellis, M.B., in "A Handbook of Canada," 1897.
(2) Wilmott, A.B., "Some Minor Minerals of Canada," 1897.
(3 *bis.*) Statistical Year Book, 1903.

are at the present time in an unsettled condition, mainly owing to the advent of electrolytic methods.[3] Wherever cheap water power is available, however, electrolytic processes will be rapidly developed, provided the raw material is obtainable within a reasonable distance.

II.—THE EXTRACTION AND REFINING OF METALS.

Almost every province in the Dominion possesses valuable mineral resources; these are rapidly being exploited, and among the metals produced in quantity may be mentioned iron, copper, lead and silver, nickel, arsenic, antimony, and, lastly, aluminum. These metals are found in the form of native iron, magnetic iron ore, iron pyrites, hæmatite, native copper, chalcopyrite, galena, native silver and ores of silver, nickeliferous pyrrhotite, gold, sulphide of antimony, and arsenical pyrites.

IRON.

The iron ores of the Dominion occur at varied intervals, from Vancouver Island on the west to Cape Breton Island and Newfoundland on the east. In Nova Scotia there are particularly rich deposits, and in close contiguity to them are found the necessary materials for smelting. Hæmatites, too, are found in all parts of Canada. One of the most valuable deposits of specular iron is at Hull, near Ottawa, which assays from 64 to 68 per cent, of metallic iron. In the Appendix (Appendix I.) will be found more particulars regarding the iron ores of the Dominion.

The Canadian iron industry dates back to the establishment of the St. Maurice forges by the French Government in 1737. Many other minor plants were subsequently built, as at Batiscan, Hull, and Bois de Paul, all in Quebec; at Furnace Falls, Mormondale, Marmora, etc., in Ontario; at Woodstock, in New Brunswick; and at Moose River, Nictaux, and Bloomfield, in Nova Scotia. They all subsequently failed, however, in consequence of the competition of Great Britain and the United States. This early failure was due as much as anything else to lack of enterprise, capital, and proper shipping facilities. The modern development of the industry may be said to date from the introduction of a protective duty on iron in 1887. The granting of bounties by the Dominion and Ontario Governments has also assisted largely in bringing about the present condition of the iron and steel industries.[4] The annual aggregate capacity of the completed and unfinished furnaces in the Dominion in 1903 was

(3) Chem. Tr. J., 23.8.02, 6.9.02, and 24.1.03.

(4) Dominion bounty on pig iron, $3 per ton produced. Ontario bounty $1 per ton on pig iron produced from Ontario ores, and 50 cents on ores not obtained in the Province; the rate of $1 to be only paid up to 25,000 tons. Bounty is at present largely reduced owing to increased production.

close on 1,000,000 gross tons.[5] Much of the iron produced is now being made into steel[6] by the Bessemer process. At Sault Ste. Marie there is an extensive plant with a capacity of 200,000 tons of ingots and 180,000 tons of finished products. There, steel rails are being made to the extent of 500 tons a day. This company has its own blast furnaces, and undertakes all the processes, metallurgical and mechanical, through which the metal goes in its conversion from ore to finished product.

At Collingwood, Ontario, the Northern Iron and Steel Company, which recently acquired the works of the Cramp Steel Company, have two 20-ton open hearth furnaces besides rolling mills from which will be turned out material suitable for machinists' and blacksmiths' use, finished steel bars, angles, fish plates, tie plates and small sections such as are used by many manufacturers. The Gilchrist Thomas is the process employed, a process which allows of ores containing phosphorus, for example, to be profitably converted into good uniform steel. The ten inch mill at the Collingwood works is equipped with underground tunnels and turtle-backs for the purpose of continuous rolling, that is to say, a bar of steel will be looped from one pass of the rolls into another pass: thus a mill of this description is enabled to roll rods and long bars. The furnaces are of the latest standard design, having air cooled end blocks and slag pockets with the regenerators under the charging platform, which is of steel and concrete.[7] Recently the sompany has begun to convert, by "cold-drawing," steel bars into wire of various gauges.

The Canada Iron Furnace Company has its principal plant at Midland, Ontario, besides several other smaller establishments in various parts of Quebec. The Midland furnace was erected during 1899-1900 on a property about 100 acres in extent, situated on the north shore of the Midland Bay. The furnace proper has a capacity of from 120 to 140 tons a day of "Midland Brand" Foundry Malleable Bessemer and Bessemer Pig Iron, and is marketed almost entirely in Ontario. The raw materials used are coke, iron ores and limestone. The coke is obtained from the Connellsville district in Pennsylvania, and is brought in by rail. The iron ores are brought in by vessel from Canadian and United States ports on Lake Superior and also Lake Michigan. The limestone is obtained from the company's own quarry, which is about 130 acres in extent, situated about three milles from the furnace. This material is brought to the furnace by scows in the summer and by teams in the winter.[8]

(5) In a letter from Mr. T. W. Gibson, Director of the Ontario Bureau of Mines, the following figures are given for 1903:

Pig Iron produced in Ontario		87,004	tons.
Steel	" "	15,229	"
Pig Iron	" Canada	265,418	"
Steel	" "	232,641	"

(6) Dominion bounty on steel, $3 per ton; $2 per ton on steel from foreign ores.
(7) Letter from Mr. J. A. Currie.
(8) Letter from Mr. A. C. Adams, Midland.

On the eastern seaboard of the Dominion are situated the works of the Dominion Iron and Steel Company, begun in 1899. Coal and limestone are found comparatively near at hand, the farthest afield mine from which the coal supply is drawn being twenty-five miles distant, while the nearest one is six miles. Nearly all the iron ore at present used is brought from mines owned by the company on Great Belle Island in Conception Bay, Newfoundland, some 400 miles from Sydney. This mine is estimated to contain 28 million tons of available ore, besides areas under the sea, which are believed to be very extensive. Analyses of the ore show it to contain fifty per cent. of iron, little sulphur, but rather too much silica, aluminium, and phosphorus. The result is a pig iron too high in phosphorus, but during the subsequent conversion of the pig into steel in open-hearth furnaces, this impurity is eliminated, and a fine quality of steel produced. For the best kind of pig iron, it is necessary to mix other ores with it, and for this purpose Cuban, Spanish, and Swedish ores are used, the result being a low phosphorus pig. Indications of large deposits of high-grade ores have been found both in Nova Scotia and Cape Breton, which, when fully developed, will in a great measure replace the foreign ores.

Limestone is obtained from the company's quarries at the Bras d'Or Lakes, about eighty-five miles, by water, from the works. It is a stone of good quality, and is found in large deposits; it acts well with the Newfoundland ore and the Cape Breton coke[8 *bis.*] The works contain four blast-furnaces capable of yielding 1,000 tons of pig iron per day; the furnace gases are utilized also to the utmost, being used to heat the blast and also to raise steam. The iron produced is partly cast into pigs and in part conveyed in a molten condition direct to the open-hearth furnaces, where it is converted into steel. Of these there are ten in number of the H. H. Campbell type of tilting basic open-hearth furnaces, having a capacity of fifty tons each. A very complete arrangement of testing the steel at intervals is in vogue, and of stamping each ingot with special marks so that the consumer can ascertain from the company at any time every particular regarding the analysis and making of the piece.

The gases produced in the coke ovens are used in the opening hearth furnaces, the other bye-products, namely, coal-tar and ammonia, being also collected. The ammonia is converted into sulphate of ammonium by neutralizing it with sulphuric acid—which can be obtained from the pyrites separated from the coal in the preliminary grinding and washing processes to which it is subjected, and is principally exported to the United States, the West Indies, and Glasgow.

(8 *bis.*) The daily shipment is 1,500 tons.

Canadian-made steel is largely exported to the United States from where it returns to this country in the form of rails and other finished products; but it is intended that this feature of the steel industry will shortly be transferred to Canadian territory. Sydney is extremely well situated as a seaport, being nearer to England than is New York, and, strange as it may appear, to the ports of South America and South Africa.[9] As far as the geographical position is concerned, therefore, Sydney possesses many advantages, while the masterly and liberal way in which the iron and steel industry has been organized and developed, points to a bright future for it in Canada.[10]

A new plant has been erected near North Sydney by the Nova Scotia Steel Company, who have at present works at Ferrona, with a limited supply of ore near at hand. Hence they import largely from Newfoundland. Their steel works are at present at New Glasgow, but a new plant is under construction at Sydney (1903), Their output, which is sold almost exclusively in Canada, approximates 100 tons of pig-iron per day and the same amount of steel.[10 *bis.*]

COPPER.

The production of refined copper can hardly be classed among the chemical industries of the Dominion, as practically only the first stage in its extraction of the metal is reached, namely, the making of copper matte, which is exported to the United States to be refined. As will be seen below, however, the refining of this metal is now being carried on in British Columbia.

Copper ores occur in great abundance, and constitute one of the most important mineral resources of the country. These are distributed over large tracts in Ontario, Quebec, Nova Scotia, and New Brunswick. The deposits consist of native copper and sulphides, the former confined principally to the Lake Superior region, the latter being more widely diffused,

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	Miles.
(9) Sydney Harbour to Liverpool (*via* South of Ireland)	2,307
New York Harbour to Liverpool	3,110
Sydney Harbour to Pernambuco	3,567
New York Harbour to Pernambuco	3,696
Sydney Harbour to Cape Town	6,467
New York Harbour to Cape Town	6,787

These figures were supplied to me by Mr. Watson Griffin, who obtained them from Captain W. H. Smith, R.N.R., Halifax. The distances from New York were compiled by the United States Commission of Navigation.

(10) Mr. Watson Griffin, who kindly supplied me with material from which the above description of the Sydney operations was written, mentioned also that a leading Scottish iron and steel magnate told him that, everything considered, Sydney, in regard to raw materials, nearness to the mark and the excellent equipment it possessed, would be the finest steel manufactory in the world. Watson Griffin, "Dominion Steel and Coal Co., Sydney;" Montreal, 1902. Watson Griffin, "The Front Door of Canada;" Montreal, 1899.

(10 *bis.*) The production of pig iron in 1903 amounted to 265,418 tons, as compared to 47,000 tons in 1893, while the proportion of the home product to the total consumption of pig was 76 per cent. in 1903 as compared with 42 per cent. in 1893.

but notably in the Sudbury region, Ontario, where it occurs with nickel. The production of copper, other than the native copper near Lake Superior, is dependent for the most part on that of this latter metal.

The British Columbia Copper Company is now turning out about seven million (7,000,000) pounds of copper a year and has an excellent converter plant at its mine. This copper is produced at a cost of about 9½ cents a pound. The product from the converter is blister copper and is sent to New York to the Nicholls Chemical Company to be refined. The Montreal and Boston Copper Company is now producing about 3,000,000 pounds of copper and is selling its matte to the British Columbia Company. The Granby Company is producing about 15,000,000 pounds of copper a year, at a cost of around 9½ cents, laid down in new York.[11]

Some idea of the advances made in the production of copper matte may be had from the fact that in 1893 the production amounted to 8,000,000 pounds, while 1903 showed an output of 43,000,000 pounds.[11 *bis*.]

Mr. A. P. Turner of the Canadian Copper Company at Copper Cliff, Ontario, has furnished some interesting particulars regarding the production of copper as carried on at the works of this company, which controls about 20,000 acres of mineral lands in the nickel district extending from Garson Township in the District of Nipissing, south-west to Drury Township in the District of Algoma, in the Province of Ontario. The company began operations in 1887, and at present is mining and smelting about 700 tons of ore per day. The ore is a mixture of nickeliferous pyrrhotite, pentlandite, chalcopyrite and diorite. The nickel in this pyrrhotite replaces about two to four per cent. of the iron. Copper occurs in the form of copper pyrites. The ore contains no arsenic or antimony, but small traces of gold, platinum and palladium. An average assay of the different mines is about two per cent. copper and four per cent. nickel.

The company has designed and just finished at Copper Cliff, a new smelting and power plant, in which are combined the latest and best improvements in the smelting world. There are larger plants, but it is doubtful if there is another in which are assembled so many up-to-date conveniences for every part of the work.

NICKEL.

The first discovery of nickeliferous deposits was made in 1883 near Sudbury, in the district of Algoma, Ontario. Previous to the discovery of nickel in this country, the French colony at New Caledonia practically

(11) Letter from Mr. F. P. Clappison.
(11 *bis*.) Statistical Year Book, 1903.

contributed the world's supply of the metal, though supplemented, in a small degree, by the Gap Mine in Pennsylvania, and by a few isolated mines in Norway and Hungary. Professor Coleman[12] states that the Sudbury ores consist of a mixture of pyrrhotite (magnetic pyrites) and copper pyrites, and in this resemble the gold ores of Rossland. In order to obtain the metal the ore is smelted into a matte, containing from twelve to twenty per cent. of nickel and about the same amount of copper, is "Bessemerized" into a regulus containing about forty per cent. of nickel and is shipped to Clydach in Wales, where its nickel content is extracted and refined by the process invented by Dr. Ludwig Mond, F.R.S., and which bears his name. The chemical principle on which this process is based is the formation, at temperatures of about 50° C., of a volatile colourless gaseous compound of nickel and carbon monoxide of composition Ni_4CO, which, on being subjected to a temperature of 180° C., decomposes, leaving metallic nickel and liberating the carbon monoxide. The product thus obtained contains between 99.4 and 99.8 per cent. of nickel. The Mond Nickel Company is the only company refining nickel within the British Empire, and it is interesting to note that at the recent St. Louis Exhibition Dr. Mond was awarded the gold medal for his process, the company receiving a similar honour struck in silver.[13] Nickel from Canadian ores is now being used in the manufacture of armour plate in constructing ships for His Majesty's navy.

What is known as the Orford or alkaline sulphide process of refining nickel is the one by which the Canadian Copper Company's mattes are treated at Constable Hook, N.J., by the Orford Copper Company. As this company (now forming part of the International Nickel Company) is the chief producer, the bulk of the nickel ores of Ontario are refined by the Orford process. An electrolytic refinery erected by the Canadian Copper Company at Cleveland, Ohio, was operated for a short time only, but shut down in 1902.[14]

The Orford Copper Company is also producing *palladium*. This metal belongs to the platinum group, and is found associated with it. The Sudbury ores are said to contain from one tenth of an ounce to one ounce per ton, and Dr. Joseph Wharton, in an article recently published [14 *bis*.] prophesies a future production of palladium from these deposits. Palladium is an interesting metal, not only from the chemist's point of view, but also from an industrial one, as its physical properties, hardness, etc., and the difficulty with which it is attacked and tarnished at atmos-

(12) 8th Report of Bureau of Mines, Ontario, page 106.

(13) A full account of the Mond Nickel Process will be found in the 8th Report, Bureau of Mines, Ontario.

(14) Letter from Mr. T. W. Gibson, Director of the Bureau of Mines, Ont.

(14 *bis*.) "Hardware and Metal," Dec. 3rd, 1904.

pheric temperatures, render it eminently suitable for replacing silver as a reflecting surface on optical instruments, for plating the finely cut scales on instruments of precision and for alloys.

ALUMINUM.

The extraction and refining of aluminum has in recent years, owing to the advent of electricity developed from cheap water power, become an important industry. At Shawinigan Falls, Quebec, are situated the Canadian works of the Northern Aluminium Company, a sub-company of the Pittsburgh Reduction Company, which also has two large factories at Niagara Falls, N.Y. The raw material, bauxite, is obtained from Alabama, Arkansas and Georgia, in the United States. The process employed is the Hall[15] process, and is a combined electrolytic and electric furnace one. The native aluminum hydroxide is first purified by mixing with sufficient carbon to reduce all impurities in it to the metallic state, the resulting iron, mixed with titanium and silicon, forming a slag after melting the mass in an electric furnace. An alternating current of low voltage is used, and the purified alumina separates out above the slag in an almost chemically pure condition. The alumina thus purified is then electrolyzed in a bath containing cryolite at a temperature of from 850° to 900° C. The action of the current sets free aluminum and oxygen, the latter uniting with the carbon anodes to form carbonic oxide. The metal is run into rough ingots weighing twenty pounds each, and is stated to contain, on an average, 99.5 per cent. of aluminum.[16] The principal portion of the product at Shawinigan is shipped in the form of ingots, although there is in addition a wire mill where aluminum wire and cable for electrical conductors are made.

The production of the Quebec works is probably 9,500 pounds per day, the value in 1902 being approximately $1,043,250.[17] It may safely be said that the three works of this company between them produce one-half of the world's supply.

LEAD AND SILVER.

These metals are derived principally from the mines of British Columbia, but there are also deposits of galena along the shores of Lake Superior, the ore from which is sent to Niagara Falls, N.Y., for reduction. The British Columbia ore is a high grade one, carrying from 25 to 300 ounces of silver to the ton. At Trail, in British Columbia, the Canadian Smelt-

(15) Dr. J. W. Richards in "Electro-Chemical Industry," Oct., 1902.
(16) *Ibid.* (average value of product is 31 cents per pound).
(17) Canadian Mining Rev., March, 1903.

ing Works have recently begun to produce commercial lead, stated to be of 99.9 per cent. purity,[18] by means of the Bett's process, which is an electrolytic one.

The Hall Mining and Smelting Works, whose Canadian headquarters are at Nelson, British Columbia, are smelting lead ores which are obtained in the Slocan and Kootenay Lakes. They employ blast furnaces, a considerable portion of the ore being first roasted in hand or mechanical furnaces, and the product of the latter briquetted. The principal markets for the pig-lead are the Orient, England, and Canada, though the home market is somewhat handicapped by the present arrangement of duties, which allows the importation of foreign corroded lead at a lower rate than that imposed on pig-lead. With a revisal of the duties a greatly increased development and revival of the lead and smelting industries is anticipated.[19] *bis.*

In 1894 the amount of silver exported, in ores, concentrates, or otherwise, was 629,655 ounces, while in 1901 the quantity had risen to over 4,000,000 ounces.[19] Despite these figures, the *Monetary Times*, Toronto, of date January 16th, 1903, says, "The silver-lead production of British Columbia is severely handicapped by the adverse competition of the United States, the European and Mexican products. The tariff is unfavourable; a higher one would be quite beneficial to the industry."

During the session of 1903 the Parliament of Canada provided for the payment of a bounty of 75c. per hundred pounds on lead smelted in Canada from Canadian ores, the maximum amount of bounty payable in any one year being $500,000, and the rate subject to proportionate reduction when the standard price of pig lead in London, England, exceeds £12 10s. per ton of 2,240 pounds. This provision has led to the revival of silver-lead mining in British Columbia. A small plant for smelting lead has been erected at Bannockburn, Ont., to be used on the non-argentiferous ores of that locality.[19 *bis.*]

ARSENIC.

A not unimportent metal found in considerable quantities in Ontario is arsenic; the chief form in which it occurs is arsenical pyrites (mispickel), which also contains gold. Its manufacture was begun by the Canadian Goldfields, Limited, at their Delora Mine, Hastings County, Ontario, in 1899. Attempts had been made, extending over the previous twenty years or so, to extract the gold from the ore found there, and, after the mine had experienced some vicissitudes, the present company acquired

(18) Letter from the Business Manager, Hall Mining and Smelting Co., Nelson, B.C.
(19) Statistical Year Book of Canada, 1901.
(19 *bis.*) Letter from Mr. T. W. Gibson.

it and obtained the rights (1896) for Ontario to the Sulman-Tweed patents (bromo-cyanide process), working it with only a modified degree of success for a couple of years, when the installation of improved machinery and the adoption of a combination of amalgamation and leaching with bromo-cyanide resulted in the recovery of arsenic from the mispickel concentrates. To accomplish this the concentrates are heated to a high temperature in specially constructed cylindrical revolving calciners, and the resulting impure arsenious oxide evolved is condensed in hermetically sealed brick chambers.[20] The crude arsenic is refined by sublimation, and contains from 99.6 to 100 per cent. arsenious oxide, the main impurity being silica in a finely divided condition.[21] It is exported chiefly to the United States, where it is used for making "Paris Green," etc. The output has increased from 113,477 pounds in 1899 to 1,347,000 pounds in 1901.[21] In time and with proper development Ontario should be able to supply the entire demand for arsenic on the continent of America.

Auriferous mispickel mines are being opened up at Lake Temagami, and concentrating works are in course of erection. The process of refining the arsenic will be an electrical one. The ores of the Haileybury region, not far distant, discovered last year, contain 60 or 65 per cent. of arsenic, but are more valuable for their other constituents, including silver, cobalt and nickel.[19] *bis*.

ANTIMONY.

This metal might almost be said to occupy the position of a bye-product in the extraction of gold. At Rawdon, in Nova Scotia, the ore (stibnite) is auriferous, and from 1898 to 1901 no refined antimony was produced, the stibnite being mined for the sake of its more precious contents[22]. It is also found in Quebec, and recent reports indicate deposits of ore in several localities of Ontario and British Columbia. The output in 1891 had fallen to $60. In 1902 the refining of the metal was renewed.

GOLD.

Gold is mined to a small extent in Ontario, in Nova Scotia and Quebec. Gold deposits are also found in the Kootenay district, B.C., in Cariboo, B.C., and in the Yukon. In the Rossland district the ore is a cupriferous pyrrhotite under a diorite cap, and from Trail on the Columbia River, where the

(20) C. Kirkegaard, in Eng. and Mining J., Jan. 31, 1903.

(21) Bureau of Mines Report, Ontario, 1901.

(22) Assays of two ores give, according to the Nova Scotia Mines Report, 1901:—

	I. Per cent.	II. Per cent.
Antimony	45.75	18.21
Gold (oz. per ton)	2.48	0.23
Silver (oz. per ton)	0.10	0.13

ore is smelted, the gold-copper matte produced is shipped to Montana for refining purposes. There is also a smelter at Nelson for the ore of the Hall mine. The Yukon territory covers in a general way the district north of Cariboo, south of the Arctic Ocean, and lying between the Mackenzie River and the Alaska-Canada boundary. Gold has been known to exist there since 1864, and has been worked intermittently since 1873. Forty Mile River, a tributary of the Yukon, was discovered to carry coarse gold in 1886, and ten years later, what is known as the Klondike, was found to contain gold also, It was first discovered on Bonanza and Eldorado creeks;[23] the news of this discovery spread far and wide, and active prospecting was the result. There are about 1,400 miles of Canadian Yukon streams, on all of which gold can be found. Mr. Ogilvie, former Canadian commissioner in the Yukon, estimates that an area of 125,000 square miles is gold bearing.[24] The former difficulties of reaching the Yukon have now been overcome; a telegraph line has also been laid by the Canadian Government from Skagway, on the coast, to Dawson. The gold is found and worked in the gravel deposits of the valleys and on their adjacent slopes, and it has been estimated that gold to the value of 95,000,000 dols. will be produced from these deposits in the next few years.[25]

The gold fields of Nova Scotia occupy the entire Atlantic coast line, and contain gold in combination with sulphides and arsenides of iron, but mostly in the free state. The following table will best convey the output of gold from Canada and its distribution.[26]

	1892	1901
	Dols.	Dols.
Ontario	7,118	243,022
Saskatchewan, N.W.T.	98,006	15,000
Yukon	.....	12,500,000[27]
Quebec	12,887	3,000
British Columbia	399,525	5,596,700
Nova Scotia	389,965	604,500
Total	907,601	18,962,222

The gold production for the Yukon in 1902 was 12,018,561 dols.; according to the United States Mints it was 14,525,275.[28]

The total output of gold in Canada in the years 1893, 1900 and 1903 amounted respectively to $976,603, $27,908,153, and $18,834,373. The figures for 1904 are not yet available.

(23) "Official Guide to the Klondike," by William Ogilvie.
(24) *Ibid.*
(25) Report of the Canadian Commission in the Yukon.
(26) Statistical Year Books, 1892-1902.
(27) Letters from Mr. B. E. Walker, General Manager, the Canadian Bank of Commerce.
(28) Letter from Hon. Clifford Sifton, Minister of Interior, Ottawa.

III.—THE MANUFACTURE OF LEATHER.

The manufacture of leather has, during the last thirty years, occupied quite a prominent position in Ontario and Quebec, and, during the past few years, through the stimulus from a larger home market and increasing sales to foreign markets, has grown greatly. As compared with a decade ago the value of the leather produced in the country may safely be said to have doubled. There are from eighteen to twenty large establishments in operation and fully fifty small ones. No tanning is done in the North-West Territories, and practically none in British Columbia. Bark, chrome, and combination tanning methods are employed, the spent bark being utilized in large establishments in specially constructed furnaces. Though the United States may be said to lead the world in the extent of leather produced, the quality of the Canadian product is not surpassed. The Canadian specialties are hemlock sole and harness, black and coloured shoe leathers, coloured and fancy side leathers for the bag, trunk and saddle trades. In Toronto there are several sheep-skin tanneries as well.

Speaking generally Quebec supplies the cheapest grades of leathers, chiefly black; Ontario the better finished lines both black and coloured. A portion of the American patterned machinery employed and formerly imported is now being manufactured in the Dominion, such as bark mills, fleshing machines, glazing jacks, drums and presses; but the most expensive and elaborate machinery is still made in the United States. The import duty on machinery is 25 per cent. The manufacture of hemlock extract in New Brunswick has already had a beginning, and will doubtless grow as the prices of bark and labour advance.

IV.—SULPHURIC ACID, ACETIC ACID, WOOD ALCOHOL, CHARCOAL AND AMMONIA.

The manufacture of commercial sulphuric acid has not yet been developed to the extent that the quantity of sulphur found throughout the Dominion would justify. There is enough sulphur in Canada to supply the entire home market with acid and even to develop a considerable export trade. Only a few firms, however, are engaged in the trade, and a large portion of their product is used in the refining of Canadian petroleum, some five million pounds being annually consumed for this purpose. Quebec, Ontario, and British Columbia are each represented in the acid industry. It is probable that the construction of electrolytic lead smelters will lead to the sulphur dioxide obtained from the galena being made into sulphuric acid, as is done at the Electric Lead Reduction Company's works at Niagara Falls, N.Y., where, it is stated, the sulphuric acid produced

yields a financial return sufficient to cover the entire cost of the process.

At London, Ontario, the Canada Chemical Manufacturing Company turns out about fifteen tons of sulphuric acid per day; brimstone, imported from the States, is used, and is preferred to the Sicilian sulphur. This company does not use pyrites on account of the arsenic it contains. The process employed is the chamber one, indeed, as far as the writer knows, the "contact" process has not yet been tried in Canada. Sulphuric acid is used by many manufacturers, such as tack, screw, nail, leather and fertilizer makers, wholesale druggists, dyers and oil-refiners. Phosphates of calcium and sodium are also made by this company, native phosphates and the animal charcoal (bone black) rejected by sugar refiners serving as sources of phosphorus. The acid phosphate of calcium is employed in the baking-powder trade instead of cream of tartar, and is claimed to be less costly, to keep better, and to restore to the flour the phosphates which, by the modern methods of milling, have been removed from the wheat.

Sulphites, bisulphites, crude acetic acid from the grey acetate of lime, chlorides of zinc and iron and Glauber's salts are likewise made.

By the destructiye distillation of wood, acetic acid, wood alcohol and charcoal are obtained; hence Canada, with its enormous supply of wood of all kinds, should be able to take a prominent place in the production of acetic acid and wood spirit. At the present time the residual charcoal from the retorts does not find a ready market, owing to the comparatively high rates for transport as compared with other fuels, weight for weight. The outlook in this direction is, however, brightening. Among the firms engaged in this manufacture might be mentioned the Standard Chemical Company, with plants at Fenelon Falls, Deseronto and Longford, Ontario, and Cookshire, Quebec; the Canada Paint Company, Montreal and Toronto; and the Lake Superior Power Company, which is said to have the largest retort plant in the world. Very keen competition has to be faced in this connection with the United States, as a combination of some 175 manufacturers practically controls the market. The crude acetate of lime produced in the distillation process is converted into acetic acid, some of which is sold for dye and colour-making purposes, while a considerable portion is exported to Europe and Australia.

The wood alcohol, obtained at the same time as the acetic acid, supplies the home market and is also exported largely to Great Britain, France, Germany, Holland, Japan, and Australia. It may be of interest to know that timber is imported from Canada by makers of wood alcohol in the United States.[29]

(29) Mr. Webster, of the Standard Chemical Co.

The total production of ammonia from all the gas liquors obtained in the destructive distillation of coal throughout the Dominion is, the writer is informed by Mr. J. G. Harvey of Toronto, about 235,000 pounds of a 28° Beaumé solution. As this quantity is in excess of what is required to supply the Canadian market by some 100,000 pounds, that amount is exported to the States. Besides the numerous trade preparations of ammonia used for household and other purposes, "aqua ammonia" and anhydrous liquid ammonia are the two principal forms in which it is prepared. The process consists in mixing milk-of-lime in suitably constructed vessels with the ammoniacal gas liquor, agitating and heating with steam and conducting the liberated ammonia through more milk-of-lime, through a drip-tank and, in succession, through oil, charcoal purifiers, caustic alkali and finally to tanks of distilled water kept cool by running water, where the gas is absorbed and the ammonia of commerce thus obtained. Manufacturers claim that the amount of water required to be used during the process reduces the profits considerably, as the gas-liquors are of a poor quality, seldom exceeding 1½° Twaddle. Anhydrous ammonia is produced from the "aqua ammonia" by a series of fractional distillations, is liquefied by pressure and stored in hundred pound welded iron cylinders. It contains 99 per cent. liquid NH^3, and finds its principal use as a refrigerant.

V.—SOAP AND GLYCERINE.

SOAP.

The soap industry in Canada is growing rapidly; at the present time some fifteen large concerns are in operation, employing in all about 2,000 hands. A branch of the well-known firm whose headquarters are at Port Sunlight near Liverpool, was recently started in Toronto, with an annual capacity of 10,000 tons. Their products are similar to those made at their other works, and their raw materials are procured from Africa, the United States, and locally (tallow). They own islands in the Pacific from which they import cocoanut oil.

Many other firms are also manufacturers on a large scale and produce all grades, from the cheapest textile and laundry soaps to the finer qualities of toilet soaps. Great advances have taken place in the industry during the past ten years, particularly in the making of the latter. The same system of manufacture obtains in England. The raw materials are mainly cocoanut oil, palm oil, and tallow, the first two in a large measure superseding the last mentioned. The market for Canadian made soap is limited, the home market is supplied and a large export trade is done with the West Indies and Australia. The competition of the United States is felt more

than that of England or France. In 1902 the value of the soap produced was approximately $3,000,000.[30]

GLYCERINE.

This necessary bye-product in the manufacture of soap is refined in some cases by the producers themselves; others sell it to firms engaged more particularly in the refining trade. Among these might be mentioned the St. Henri Chemical Company, of Montreal, who buy waste lyes from the soap manufacturers, recover the salt from the lye, refine the glycerine, and sell to the makers of nitro-glycerine. The capacity of these works is 10,000,000 pounds of waste lye yearly.[31]

VI.—REFINED CHEMICALS AND DRUGS.

There are very few makers of refined chemicals in the Dominion. The small demand for pure chemicals is mainly accountable for the lack of local manufacturers, the market being necessarily a small one, and most buyers of pure chemicals for laboratory uses are apt to demand articles of the make of one or other of the large and old established German or English houses. One can hardly doubt but that the Canadian maker must desire a higher tariff on imported material. Of heavier chemicals, however, the Canadian Process Co. has recently begun the manufacture and the work is proving very successful. Such products are bisulphite, sulphide, thiosulphate (hyposulphite), sulphite and sulphate of soda, lime, and zinc salts, lactic acid, casein, etc. Messrs. Lyman Bros. and Company are continuing to extend along the lines of refined chemicals, their gold and silver salts being much in demand. Along with these they produce and refine such high grade chemicals as chloroform, ether, iodide of potassium, bromides, scale preparations, iron and zinc salts, acids of phosphorus, syrups, tinctures, and flavouring extracts. Most of the raw materials are imported. In the drug department this firm has probably the best grinding machinery in Canada, where, besides their own work, they do a considerable amount of grinding for other firms. In the strictly pharmaceutical business, Messrs. Parke, Davis and Company, Walkerville; H. K. Wampole, Toronto; F. Stearns, Windsor; and John Wyeth and Bro., Montreal, have manufacturing establishments. Recently the brand "Made in Canada" has been much in evidence, and many buyers prefer such goods, even if they are slightly more expensive, to the imported article.

A few years ago the Liquid Carbonate Company of Toronto commenced the manufacture of carbon dioxide on a commercial scale, and is now

(30) Mr. Knight, of the Sunlight Soap Co.
(31) Letter from the President of the Company.

producing some two tons a day. The methods employed for obtaining the gas are from the action of an acid, such as sulphuric acid, on chalk, dolomite or sodium carbonate, and by the combustion of coke, while it is also got as a bye-product from the fermentation vats in breweries. The gas, after being washed and purified, is compressed, cooled, and in liquid form is forced into steel cylinders at a pressure of from sixty to eighty atmospheres. (The cylinders are tested to a pressure of over two hundred atmospheres). This liquid gas finds a market from the Atlantic to the Pacific, and is used for aerating mineral and artificial waters, for forcing beer from barrels in the cellar to a higher level, and at the same time preserving it from deterioration. It is also used in the refining of sugar, as a motive power in spraying trees with a germicidal solution, and in the laboratory for producing low temperature mixtures. Numerous useful bye-products are a consequence of the process of production of carbonic acid, such as fine clay used by paper-makers, Epsom salts and Glauber's salts—all of which are employed in many industries and command a ready sale.

VII.—FERTILIZERS.

Mineral phosphates, in the form of apatite, are found in the Ottawa Valley, Ontario, but the deposits have not been worked for several years. About 1891, in which year the phosphates mined were valued at $50,000, a falling off began in the output of this mineral, which continued up to 1902, when the amount mined was hardly worth recording. This industry is on the increase again, however, and last year saw a production valued at some $8,000. This state of affairs has been brought about mainly by the large supply of easily-worked phosphates found in Florida and Carolina, U.S.A., much of which is obtained by dredging. It may be mentioned, however, that a certain amount of apatite is made use of in the Province of Quebec by the Buckingham Electric Reduction Company, who manufacture phosphorus therefrom.[32]

Sulphate of ammonia is manufactured at the works of the Dominion Iron and Steel Company, Sydney, N.S., whose products are supplied to dealers and others engaged in the fertilizer business. The ammoniacal liquors of the Quebec, Ottawa and Toronto Gasworks are worked up at the latter city by the Michigan Ammonia Company.[33] In Montreal, one firm at least, makes sulphate of ammonia, and at one time the gas works there utilized their own liquors for its production. Latterly, however, the gas liquor was exported, to be dealt with by a firm in the United States.

Quite a number of other fertilizers are produced in the Dominion from

(32) Minerals of Quebec: published by the Provincial Government.
(33) Letter from Mr. Macfarlane, Chief Analyst to the Inland Revenue Department.

refuse matter, such as blood, tankage, bones, and offal, besides natural phosphates. Ontario, New Brunswick, Quebec, Nova Scotia, Prince Edward Island, and British Columbia, all produce fertilizers, more or less.[34]

VIII.—Coal-Tar and Asphalt.

Very little tar distillation is carried on in the Dominion, owing mainly to the tar produced in the gasworks being too thick for treatment with any degree of success. It is mainly used for saturating paper, which is employed largely as a waterproofing material by builders. Some is boiled down into pitch, but about one half of the tar produced is exported to the United States. There is a small distilling plant at Hamilton, Ontario, which the writer understands, was, up to eighteen months ago, the only one of its kind from which coal-tar oils were produced in Canada. The Dominion Iron and Steel Company at Sydney obtain a considerable quantity of coal tar from their coke-ovens. This, at one time, found a market in the States, in Montreal and other points in Canada, but recently arrangements were made with an English chemical company to locate at Sydney with a view to utilizing all the coal-tar produced from the coke-ovens. The works, which are one of the largest on the continent, are now in operation and doing a large business in Canada, Europe and the United States; the demand for the company's products in Canada is not sufficient, hence the European and American exports. The present products are pitch and the various grades of benzol, creosote-oil and carbolic acid.[35] Large extensions are looked for from this company, which will be guided by the motto *festina lente*, and as opportunity offers, will branch into the production of other commercial commodities arising out of coal-tar and its distillation products.

Asphalt.

Asphalt occurs naturally in several varieties as albertite, found in King's and Albert Counties, N.B., and as maltha, one of the stiffer petroleum compounds, which is not of much importance however, being almost too hard for use in street paving. Up to 1898, albertite was employed in gas-making, and much of it was shipped to the United states; but the original supply is now exhausted.

IX.—Calcium Carbide, Carborundum, Corundum, and Graphite.

Calcium Carbide.

The production of this substance on a manufacturing scale dates back only to the year 1891, when Mr. T. L. Willson, of the Willson Aluminum

(34) Inland Revenue Bulletin, No. 81, 1902.
(35) Letter from Mr. John Craven, Sydney, 2nd Feb., 1905.

Works, at Spray, N.C., accidentally obtained carbide whilst trying to reduce lime by carbon in the electric furnace. Instead of metallic calcium resulting—which was to be employed in preparing aluminum—a hard, almost black, substance was got which reacted violently with water, giving lime and an inflammable gas clearly recognizable as acetylene. The author was privileged, through the courtesy of Lord Kelvin, to have at one time in his possession some pieces of the first carbide made by Mr. Willson at Spray. Acetylene being a powerful illuminating agent and readily obtained from carbide, the development of the carbide industry on a commercial scale followed this discovery as a natural consequence. The industry has progressed by leaps and bounds during the past decade, in Europe even to the extent of over-production.[36] Two carbide works are in operation in Canada using water as their source of power, the Ottawa Carbide Company, and another important company is the Shawinigan Carbide Company of Shawinigan Falls, Quebec. The process of manufacturing consists in fusing together burned lime and ground coke in the electric furnace; the temperature required is not so high as that needed in other operations for which the electric furnace is employed, notably the making of carborundum and graphite. The reaction taking place in the furnace results in a transference of the oxygen of the lime to a portion of the carbon with the formation of carbon monoxide and carbide of calcium.

The present market value of carbide affords considerable profit to its manufacturers, and the increasing popularity of acetylene as an illuminant ensures a brighter future for the industry. In Ontario several towns have already had acetylene installed for house and street lighting, the gas being generated at a central station and distributed in pipes to the consumers.[37] At the generating station the gas is purified by a special process before use, which obviates all the disadvantages inseparable from the employment of small generators—automatic or otherwise—by individuals, who in most cases have neither the time nor the scientific skill necessary for the proper production of the gas, simple as it may appear at first sight.

CARBORUNDUM.

Ten years ago the very name "carborundum" was unknown; it is due entirely to the advance made in the development of electrical power, obtained from the immense waterfalls of the American continent, that this as well as other materials are now in daily use throughout the world.

(36) Italy alone possesses enough carbide plants to supply the whole of Europe. Dr. J. W. Richards, in "Electro-chemical Industry," Sept. 1902.

(37) Worked under patents held by the Burgess Gas Process Co., Canadian Pat. 73,040, Sept. 10, 1901; Eng. Pat. 241, Jan. 3, 1901; Amer. Pat. 701,995, June 10, 1902.

The history of carborundum, may well be likened to that of carbide, its discovery being accidental. Mr. E. C. Acheson, whose patents are employed in this industry, was endeavouring to obtain crystals of carbon by melting together clay and carbon, the latter of which it was hoped might crystallize from the resulting reduced aluminum. Hard crystals were found after the fused mass had cooled, the component parts of which were concluded to be carbon and aluminum, and for which he invented the name "carborundum." Analysis, however, proved the new substance to contain silicon and carbon, and only a small quantity of alumina. Further experiments were made with mixtures of sand, carbon and salt as a fluxing agent, and large crystalline masses of carborundum were obtained. The substance thus formed corresponds to the formula CSi, is extremely hard, and is used in place of emery and corundum. In the manufacturing process the materials employed are sand, coke, salt, and sawdust; the coke is reduced to kernels of a certain size, to be used for making the "core," and other portions are ground to a fine powder for mixing with the charge of sand and salt. The original form of furnace was fitted with a pair of carbon terminals, which could be moved longitudinally, and was essentially an arc furnace, the chemical changes taking place being due to the high temperature of the arc passing between the carbon terminals. In 1895 this form was abandoned and a continuous electrical connection made between the terminals by the introduction of a "core" of granulated coke. By regulating the diameter of the core it could be heated to a sufficiently high temperature to convert the surrounding mixtures into carborundum. In the modern form of furnace the brick ends and carbon electrodes, with the necessary terminals for connecting up the current, are the only permanent portions. The charge, consisting of sand, finely-ground coke, and sawdust,—added to render the mixture more porous and consequently allow the gaseous products to pass through the mass—is placed in the furnace till it is on a level with the lower edge of the carbon electrodes. The coke "core " is then filled in, made into cylindrical form by hand, and finally surrounded at its sides and on the top by the remainder of the charge. Care is taken to prevent the mixture coming in contact with the carbon terminals, and necessary retaining walls are built up of bricks as the charging operation is proceeded with. The current is passed for thirty-six hours, and after cooling, the walls are taken down, unused "charge" raked off, and the outer crust of carborundum exposed. A cross section of the contents of the furnace presents many interesting characteristics. In the centre is the core, which has been, to a large extent, converted into amorphous carbon and graphite. From this there radiate beautifully coloured carborundum crystals to a distance of from ten to twelve inches. Next a thin inner crust of amorphous carborundum of a light green colour is met with, then the outer crust, also

amorphous, and beyond this, the unchanged mixture.[38] A curious effect is observed near the core, where the temperature is highest; here are found crystals of carborundum, from which the intense heat has volatilized the silicon, leaving "skeleton" crystals of graphite, while the silicon, passing outwards oxidizes to silica, and often presents the appearance of spun glass. Silicon itself has been found in the cracks in the bed of the furnace.[39] The carborundum is finally crushed, washed, and graded for the market.

Carborundum has a lower specific gravity than emery, and finds its principal application in the manufacture of wheels, stones, razor hones, rubbing bricks for marble dressing, paper, and cloth. The Canadian works of the Carborundum Company were destroyed by fire in 1903 and have not been re-built. This plant was comparatively small, only operating 200 horse-power. The factory, however, supplied the Canadian market, thus avoiding the payment of duty. The writer was informed by Mr. Acheson that most of the Canadian product was exported to Scotland, to be used there in finishing granite. The estimated cost of the crude crystals is 2.5 cents per pound, that of the treated powder, 4.5 cents per pound, while the selling price averages 9 cents per pound.

CORUNDUM.

The natural corundum industry of Ontario, which is of recent origin, is, however, now steadily growing in amount and value of output. The production of corundum in 1901 had a value of $53,115, and in 1903, $106,332, and in 1904 over $3,000,000.[40] The chief producing company, the Canada Corundum Company, has just completed a new mill of greatly enlarged capacity, and the other operating concern, which formerly exported the corundum-bearing rock to the United States, after cobbing it merely, is now crushing and treating it on the spot. Two additional companies are in process of organization for producing corundum.[41]

To the Canada Corundum Company, of which Mr. B. A. C. Craig is the president, may be accorded the credit of having placed the natural corundum industry of Ontario on a firm basis. Craig Mountain is said to be the largest deposit of corundum in the world. The hardness of this substance has long been known, and under the name of emery it has, in an impure state, been used as an abrasive agent. The product of this mine is said to contain from 95 per cent. to 98 per cent. crystalline alumina, and from letters the writer has seen, its hardness and cutting qualities seem

(38) Illustrated Catalogue No. III., Carborundum Company, N.Y.
(39) Electro-Chemical Industry, Vol. I., No. 2.
(40) Letter from Mr. B. A. C. Craig, President of the Canada Corundum Company.
(41) See 19 *bis*.

to have recommended it to consumers alike in Europe and on the American continent. Results are always the best tests of the efficiency of any agent, and the rapidly increasing market that Ontario's corundum is finding is sufficient evidence of the quality of this material. The Craig Mine is now putting out about ten tons a day, and the management confidently expect a considerable increase in the spring.[42]

GRAPHITE.

Though no company for the manufacture of graphite has yet been capitalized in Canada, the production of it by the Acheson process is carried on to a small extent in the Canadian branch of the Carborundum Company at Niagara Falls. The formation of the "skeleton" crystals referred to above suggested making use of the decomposition of carborundum for making graphite itself. The inventor's patents include the production of graphite in the form of pure electric-light carbon, by subjecting impure carbon to a high temperature for a sufficient length of time to volatilize the impurities;[43] the conversion of carbon into graphite by mixing with such metallic oxides as would be capable of forming metallic carbides, to be subsequently decomposed;[44] the conversion into graphite of such natural carbonaceous materials as contain uniformly intermixed through them metallic oxides sufficient to produce carbide, and thence graphite.[45] These processes throw considerable light on the scientific principles underlying the formation of this substance.[46]

X.—THE CEMENT AND PLASTER INDUSTRY.

The manufacture of Portland cement is mainly confined to Ontario, though one establishment—the Crescent Cement Works—is situated at Longue Pointe, in the Province of Quebec. In Ontario there are some fourteen companies and eight factories in operation, and throughout this Province are found the necessary raw materials (clay and marl) of an excellent quality. The development of the industry has been rapid, and has all taken place within the past few years. The most improved method of procedure is as follows: the marl is thoroughly mixed, mechanically, with water into a thin paste, and the same operation is performed with the clay. The two fluids are mixed thoroughly in the required proportions, and in a pasty condition are pumped into steel rotary calciners, about seventy feet in length and six feet in diameter, set at a slight angle to the

(42) See note 40. An account of the Corundum Industry of Ontario will be found in the "Canadian Mining Review," Vol. XXIII, No. 10, (1904).

(43) U.S. Pat. 542,982 of July 23, 1895.

(44) U.S. Pat. 568,323 of Sept. 29, 1896, and No. 617,979 of Jan. 17, 1899.

(45) U.S. Pat. 645,285 of March 13, 1900.

(46) Electro Chemical Industry, Vol. I., No. 2.

horizontal. These rotary calciners are the great feature of the Canadian cement plants. This form of kiln is originally of English origin, but has only been brought to its present effective condition since its introduction to this country. In the interior of the kiln are "channel-irons" running from end to end. At the lower end fuel is introduced in a particular manner, and the burning gases pass through the entire length of the kiln, and are allowed to escape at the upper extremity. At this latter end is introduced the "slurry" of the mixed ingredients, which becomes dried and finally calcined in the slow passage from one end to the other. The revolving irons carry the "slurry" up with them as they rise, and on reaching the top it falls, under the action of gravity, through the burning gases, being subjected at the hottest part to a temperature of 3,000° F., when combination takes place between the constituents of the fused mass, and the resulting "clinker" emerges into the vessel destined for its reception. The drying and calcining is thus performed in one operation, and no preliminary pressing of the material into bricks is required.[47] At the works of the National Portland Cement Company, recently erected at Durham, Ont., a great saving of time is effected by cooling the clinker in vessels drawn by an endless chain through a stream of water below the ground level. After cooling in this manner it is ground to a fine powder, and packed in bags or barrels ready for use. The whole operation by this process occupies only eight hours, a period of time which will be appreciated by all acquainted with the older methods. At Durham the raw materials are brought from the natural deposits, which are close at hand, calcined, cooled, ground and packed by means of a continuous series of mechanical conveyers from one part of the establishment to the other. This company has another plant in course of erection at Hull, P.Q., on the Ottawa River, which is intended to supply the Eastern Canadian market.

Several articles have appeared lately in the public press[48] pointing out that a possible over-production of cement may be the result of the numerous large concerns which are already in operation or are about to be started. Whether or not this will take place in the immediate future depends, naturally, on the general prosperity of the country and the consequent demand for building materials. Certainly cement has gained considerable reputation as a substitute for stone, as can be seen by the extent to which it is made use of by architects. It can be readily moulded into any form and may then be dressed to represent the natural article. If it can ever oust stone and brick from their present position depends, not only on its comparative cost, but on the quality of cement put out by manufacturers. One case of a collapse due to an admixture of a single bag of inferior material and the whole fabric of the cement industry

(47) The Portland Cement Industry: "Queen's Quarterly," Jan. 1903.
(48) "*The Globe*," Toronto, March, 1903, and other papers.

as supplying a substitute for the older building materials, will be in danger of a similar fate. The total output of Portland cement in 1902 was valued at 1,028,618 dols.,[49] and in 1903 at 1,166,497 dols.[50]

Gypsum is found in considerable quantities in Nova Scotia and New Brunswick. At Windsor, N.S., there are immense deposits; the beds found in the vicinity of Hillsborough, N.B., are, however, very large and of great purity, and form the basis of the most extensive operations.[51] It is also found in Ontario, and plaster works are located at Paris in that Province. In 1901 active operations were begun at Gypsumville, Manitoba. The industry, however is principally located in New Brunswick. Drawbacks in the way of freight charges, inadequate shipping facilities, and the competition offered by manufacturers of plaster of Paris in the United States, kept the industry from developing until the Intercolonial Railway was opened and the increased duty on American plaster imposed, when the New Brunswick plaster, quarried and prepared at Hillsborough, came to be firmly established on the Canadian Market. In manufacturing plaster of Paris, the stone is first dried in the air and ground—not burned in lumps as is still done to a considerable extent in England and on the Continent of Europe, and the pulverized material subjected to a process of calcination in kettles, of a capacity of sixty barrels of 300 pounds of the calcined plaster, furnished with lids and stirring arms which keep the material in constant motion. When the required temperature has been reached (285° F.), the plaster is removed and packed in paper-lined barrels for market. Analysis of the Hillsborough gypsum shows it to be 99.88 per cent. $CaSO_4$.[52] The principal markets for plaster of Paris are Canada, the United States, and South Africa, while the crude gypsum is exported largely to New York and other portions of the States, being used for making plaster for walls and ceilings.[53] According to the Geological Survey Reports for 1902, the gypsum produced in Canada during that year amounted to over 332,000 tons, valued at 356,317 dols.

XI.—CARBOHYDRATES: (A) THE REFINING OF SUGAR; (B) THE BEET-SUGAR INDUSTRY.

The hoped-for developments in the production of sugar from beets in Ontario and Southern Alberta, referred to in the first edition of this paper (1903) have not come up to the expectations either of the writer or of the public as will be seen from the sequel. Statistics show that during

(49) Geological Survey of Canada: Mineral Products, 1902.

(50) Stattisical Year Book, 1903.

(51) Geological Survey of Canada: The Mineral Resources of New Brunswick, 1899.

(52) Analysis by A. A. Breneman, of New York, in Mineral Resources of New Brunswick, Geological Survey of Canada, 1899.

(53) Letter from the Manager, Albert Manufacturing Co.

the last decade cane sugar has increased in production about 200 per cent. Judging from present appearances, and allowing for some slight tariff alterations, the increase in Canada should soon be in proportion to that of other countries.[54]

Raw sugar is imported from Cuba, the West Indies, Java, Manila, the Brazils, Mauritius, and the Continent of Europe. The most improved machinery and processes are employed, refined sugars and syrups being the staple products,

Belgium supplies to Canada the largest proportion of sugar, the imports from that country amounting in 1901 to 127,931,553 pounds; from Germany in the same year 83,941,290 pounds entered the country, the total imports being 336,694,833 pounds valued at close on $8,000,000.[55]

BEET SUGAR.

The most interesting point connected with the sugar industry is the way in which the production of sugar from beets cultivated on Canadian soil has become, in the past few years, an important factor in the country's progress. As far back as 1872 the Dominion Government sent a special agent to Europe to make a study of the industry. A bounty of $25,000 afterwards increased to $70,000 was offered by the Quebec Government in 1875 to the first successful factory to be established in a situation approved by the Government. This led to the establishment of a company known as the Union Sucriere du Canada, which, in 1881, erected the first of four proposed factories at Berthierville, Que.[56] This establishment was unsuccessful and only operated for a few days, mainly owing to the failure of the beet crop. After passing into other hands the plant was bought by an American company and removed to Eddy, New Mexico.[57] Another company was, in the same year, organized at Farnham, P.Q., not far from Montreal, which after some vicissitudes, did not deem its success sufficient to warrant a continuation of its operations, so sold its plant to a company at Rome, N.Y., in 1897. A third company, known as the Pioneer Beet Company started operations in 1881, at Coaticook, P.Q.,[59] and was successful in part, receiving a subsidy of 35,000 dols. from the Government, but it, too, closed its doors in 1883. The causes to which these failures may be attributed were lack of capital and enterprise, and the indisposition of the farmers to cultivate beets. The Agricultural Department of the Provincial Governments, however, continued experimenting with various kinds of beets and studied the conditions most favour-

(54) Letter from Mr. D. A. Gordon, President of the Wallaceburg Sugar Company.
(55) Essay, Mr. Read, University of Toronto.
(56) Report of Dominion Government on beet sugar manufacture in Canada.
(57) Letter from the Manager of the Dresden Sugar Co., Ontario, now removed to Michigan.

able to their successful growth. For some years past the Ontario Agricultural College at Guelph has, as a consequence of the excellent results obtained at their experimental stations, been carrying on an educational campaign among the farmers of the Province. As a result of this the quality and tonnage of beets now grown in different parts of Ontario surpass those of many American States. The climate of this Province, with its sunshine and long autumns, is peculiarly favorable to the cultivation of the beet, which takes about four months and a half to reach maturity. It requires, however, to be demonstrated to the farmers that the cultivation of beets will pay them better than other land produce before the requisite supply of suitable material will be obtained. That the profits are large can be gathered from the fact that wheat yields in Ontario $15 an acre per annum, oats, $9.74, and beets for sugar, $60. In the last case the cost of production is necessarily large, owing to a great amount of labour being required, but, all the same the profits to the farmer should, with skilful treatment, be at least $30 per acre per annum. The beet tops are of value as a fertilizing agent owing to the salts they contain, and find a use also as a food for cattle. In 1901 beets were grown —under instructions from the Agricultural Department—in fifteen districts of Ontario, and the average yield per acre was over seventeen tons of a high quality of beets which gave an average of 15.6 per cent. of sugar of an average purity of 87.7 per cent. All this points to a future for Ontario as a sugar-producing country; this fact has been fully realized by the Provincial Government, which offered a bounty of $275,000 for three years,[58] and at its recent session extended this bounty for a further period of two years, to be distributed among factories according to the amount produced. Four companies were organized a few years ago, namely, the Wiarton Beet Sugar Company (capital $500,000) which has since been shut down; the Dresden Sugar Company (capital $600,000) which has now removed its factory to Michigan; the Wallaceburg Sugar Company (capital $500,000) and the Ontario Sugar Company, of Berlin (capital $1,000,000); each of these companies received a bonus from the town where it was situated, averaging $28,000. The capitalization of a company engaged in this industry depends entirely on the size of the plant, a general estimate of $1,000 per ton of beets per day may be considered a fair calculation of what would be required.

Two companies only are thus in the field this year, and it seems reasonable to expect that both factories will increase their output over that of 1903. The nearness, geographically speaking, of the Wallaceburg and Dresden concerns to one another—some nine miles apart only—militated against their success, and it is to be hoped that now the former is, so to speak, alone, it will do better than heretofore.

(58) 1, Edw. VII., Cap. II, (1901).

Beet sugar factories have also been established in Alberta, in the North-West Territories of Canada. Since 1893, an area of about 300,000 acres has been made productive by means of the irrigation system of the Canadian North-West Irrigation Company, and a portion of this area has been utilized for beet cultivation, principally by the Mormon settlers. The most important factory has been established by the Knight Sugar Company at Raymond, south of Lethbridge, on the Canadian Pacific Railway. The capital of this company is $1,000,000. The area intended to be planted with beets is 3,000 acres, and the daily capacity of the factory will be 400 tons of beets per day. The only difficulty which the industry is encountering in the North-West is the scarcity of labour.[59] This is due partly to the scanty settlement of the country, and partly to the superior attractions of the mining regions, which are situated at no great distance.

A plentiful water supply, lime, and source of power, are necessary for the profitable prosecution of the industry; all this has been carefully considered in locating the factories enumerated above, steam power being employed for pumping and the working of all machinery. There is room for many more factories in the Dominion; according to Dr. A. B. Shuttleworth, Chief Agriculturalist to the Ontario Sugar Company, whose name is indissolubly connected with the development of beet cultivation, it would require over thirty refineries each of 600 tons capacity to supply the home market alone.[60]

The working season of a factory runs for about 100 days, operating continuously. The cost of the sugar is from three to three and a half cents per pound, and the profits to the makers are estimated at fifty cents per ton of beets used. This would mean that in a factory of 500 tons capacity, working for 100 days, the profits would amount to $25,000.

The scope of this article does not allow of any detailed consideration of the working process by which the sugar is extracted frm the sliced beets and crystalized. New proceses are being employed for utilizing the residual molasses. This is treated for the recovery of the sugar in some part, and also for the production of alcohol by fermentation. An American company in 1901 produced 915,000 gallons of alcohol in this way, of a quality considered to be quite equal to the grain product. Another new process is that of the manufacture of syrup from the beet instead of sugar; forty gallons of this can be obtained from a ton of beets, which, at thirty cents a gallon, means a return of $12 per ton of material used, while the product in sugar yields only from $7 to $8 per ton of beets. The

(59) Letter from Manager of works at Raymond.
(60) Berlin News Record, Nov. 8, 1902.

beet-pulp refuse is also being largely used as a food for live stock, for which purpose it is extremely suitable owing to its nitrogen contents. In this connection a new process has been introduced for drying the pulp, which entails an expenditure of $5 per ton, but, as the dried pulp is sold at $6.25 per ton, a clear profit of $1.25 is thus secured to the manufacturer.[61]

The production of sugar from Canadian grown beets is a new and, it is to be hoped, rising industry which offers great scope for some co-operative arrangements between the companies and the farmers. It should give an impetus to agriculture, afford employment to thousands of unskilled workpeople, and, as an important industry, be a lasting benefit to the country. Whether or not the growing of beets will become popular remains to be seen; the present quality is as yet not so good as was expected, but much may yet be done in the way of improvement by careful cultivation.

The following communication, dated March 6th, 1903, from Mr. George Elsey, manager of the Dresden Sugar Company, conveys some idea of the position of the industry from the point of view of the manufacturer and its possible future:

"At the present time there were four factories which operated this last season, and from what we are able to learn the results were as satisfactory as could be expected under the existing conditions, that is, the rain fall last summer damaged the beet crop from fifty to sixty per cent., both in the United States and in Canada. The balance of the crop, on account of wet weather, cost considerably more to raise than what was necessary. It was unfortunate that this should occur in the first season that the factories were started in Canada, as it was very disappointing, but most of the farmers have told us that they were surprised at the amount of rain the beet would stand, and in several instances where they could harvest the beet crop, the corn and other crops were ruined. After we have had a seasonable year and it will be demonstrated to the farmers that there is more money in raising sugar beets than any other crop that grows, the four factories now in existence will get their supply of beets within hauling distance of the factories. . . . Our farmers know well that the Michigan farmers obtain about a dollar a ton more for their beets than they do, and they also understand that it has cost as much in money and labour to raise a ton of beets in Canada as it does in Michigan or any part of the United States. They therefore feel dissatisfied, and are clamouring for more money, which the companies would be glad to pay if they could sell their sugar for the same price as the American Beet Sugar refineries. The present Canadian sugar tariff is such that it would not allow any

(61) In the above I have drawn largely from an essay on the beet-sugar industry by Mr. E. R. Read, a student in the Department of Political Science, University of Toronto, who kindly placed his papers at my disposal. Also from Dr. Shuttleworth's article in the "*Berlin News Record*," 1902.

more sugar refineries to be built in Canada. The companies that are already here have the experience of what this tariff can do. It allows sugar that has been refined in the United States to be shipped in here and undersell Canadian refined sugar, which means a loss to the refineries and to the Canadian people. It allows raw beet sugar to be imported at a price that will prevent the farmers from taking hold of the beet industry as they should. Canada is sending to Germany and other foreign countries about $1,000,000 per month for raw beet sugar, and the naturally yearly increase of consumption is about eight per cent, so that the future of the sugar beet industry, under a proper tariff, would be a lasting one and a great benefit to the farming community."

XII.—NATURAL GAS AND PETROLEUM.

NATURAL GAS.

The existence of natural gas in Ontario was first discovered in 1889, being found in two well-defined areas, as the Essex county field and the Welland county field. It is chiefly near Buffalo, on Lake Erie, and near Windsor, Ontario, that the largest supplies are met with, though practically it may be got in nearly any part of the Niagara peninsula in small quantities. In 1901 there were 158 wells in operation, and 368 miles of piping were needed to distribute the gas. Much of the gas produced in Essex county was formerly led across the river to Detroit by pipe lines, but on representations made by the people of the Essex district to the effect that the supply of gas was not sufficient for home consumption, the Ontario Government passed an Order in Council in October, 1901, prohibiting the gas from the Essex field being exported to the States. None of the product of this natural gas field is therefore now being sent across the Detroit river; it is, however, still exported from the Welland field to the American side of the Niagara River, chiefly to Buffalo, N.Y. It may be mentioned that the landowners on whose farms the wells are located get their gas free in addition to being paid for the use of their lands.[62] The value of the gas produced in Ontario during the last ten years shows considerable fluctuations, being much less in 1903 than in the previous year, due, no doubt, to the Government prohibiting its export.[63]

PETROLEUM.

This is one of the chief mineral products of the Dominion, though as yet the output is not sufficient to meet Canada's needs. The principal seat of the industry is at present in Ontario, where commercial quantities

(62) Report of the Bureau of Mines, Ontario, 1902.
(63) Statistical Year Book of Canada, 1903.

are found in the counties of Kent and Lambton. In the former there are two oil fields, one at Oil Springs, extending over 1,200 acres, and the other in the Petrolea district, 20 miles long by 2 wide.[64] In Lambton county the industry dates back to the year 1862. Petroleum is also found in Quebec, Nova Scotia, New Brunswick, and boring operations that have in recent years been carried on at Athabasca, near Edmonton, in the North-West Territories, point to a likelihood of that part of the country contributing largely to the future supply of mineral oil.

The industry is now one of the most highly organized in the Dominion; the system of drilling and pumping now used—the "jerker-line" system enables a well yielding from eight to ten gallons a day to be profitably worked. This system has gained for itself a world-wide reputation; it is used in Galicia, Russia, Afghanistan, Burmah, India, Italy, France, California, and Australia. Its advantages are numerous; a central engine can operate a large number of wells; on one property near Petrolea, 233 wells, scattered over an area of 400 acres, are worked by a single engine. It is estimated that to sink a well of about 500 feet in depth costs only $125.[65] In 1900, there were approximately 10,000 wells in operation, yielding on an average seventy-one barrels of oil each.

The refining side of the petroleum industry is largely in the hands of the Imperial Oil Company,[66] which some years ago absorbed several other concerns, and of the Canadian Oil Refining Company. The plant of the former at Sarnia has a capacity of 60,000 barrels of crude oil per month, and the market for their products reaches from Halifax to Vancouver. Many of the bye-products of the refining process find a market in England and in Spain. The latter company have erected an up-to date plant at Petrolea, on the site of one which was in operation some years ago, where all the products will be manufactured that modern science shows can be obtained from petroleum.[67] Improvements in methods of retorting have recently led to considerable quantity of the crude oil being used for gas making, three and a half million gallons being an estimate of the amount so employed.[67]

There has been a slight falling off in the production of oil during the past years; calculated as "crude" oil, the output in 1901 was 27 millions Imperial gallons, and in 1901 a little over 26½ millions.[68] In 1903 it fell to some 16 million gallons. A slow process of diminution seems to be going on in the area at present productive, and a falling off must be looked for

(64) The oil is found at depths varying from 370 to 400 feet.

(65) This and much of what is given here on natural gas and petroleum is from a paper by Mr. W. J. K. Vanston, read before the Canadian Section of the Society of Chemical Industry in Jan. 1903.

(66) Capital stock, $1,000,000.

(67) Bureau of Mines Report, Ontario, 1902.

(68) Statistical Year Book, 1903.

from year to year unless this is counteracted by an extension of the oil-bearing territories.[67] Probably, the field about to be exploited in the North-West will alter the position somewhat, and an increase in the output may be confidently looked for.[69]

XIII.—PULP AND PAPER.

PULP.

As timber is one of the chief natural products of the Dominion, it is only to be expected that Canada should figure largely in the wood pulp industry; the figures that might be given to indicate the number of cords of pulp-wood available throughout the country are so large that one could hardly grasp their real significance. The industry is not so young as many others that have been considered; in the census of 1871, no pulp-making plants are mentioned; in 1881, there appear five mills, employing 68 men, and having an output valued at $63,000; in 1891 there were 24, with a yield valued at more than a million dollars; while 1903 shows some 39 factories, from which the exported pulp alone amounted to over five million dollars.[70] The area of pulp-making operations is not confined to any one Province, New Brunswick, Nova Scotia, Quebec, Ontario, and British Columbia are all represented in the industry.

The principal woods employed for pulp-making are white and black spruce, balsam, poplar, and pine; spruce[71] and balsam are those most generally used, on account of the special quality of their fibre and their colour, pine being utilized mostly for chemical pulp. The two main varieties of the pulp are *mechanical* and *chemical*. The former is obtained by grinding spruce logs to powder, the logs being pressed against a rapidly revolving grindstone, with water constantly supplied to prevent the friction causing a rise in temperature. A liquid pulp is thus obtained from which the water is squeezed by hydraulic machinery, a pressure of many tons to the square inch being employed. The resulting pulp still contains water, however, to the extent of from 50 to 60 per cent., though some works—notably those at Sault Ste. Marie—have introduced a machine specially constructed for the purpose of removing this large excess of moisture. Where the pulp is to be made at once into paper, this drying process is unnecessary. The specially dried pulp resembles paper very closely in outward appearance.[72] Chemical pulp is prepared by disintegrating and

(69) Total value of products of petroleum in Ontario in 1901, $1,467,940, Bureau of Mines Report 1902.

(70) Statistical Year Book, 1903.

(71) In 1894 it was estimated that Canada contained between 38 and 40 per cent. of woodlands and forests, or about 1,400,000 square miles, one-half of this being spruce. The spruce area is thus 450 million acres. In all there are 4,500 million tons of pulpwood in sight. "Pulpwood of Canada." Pan-American Exhibition pamphlet, published by the Geological Survey, 1901.

(72) The Sault Ste. Marie Works used (1903) some 200 tons of spruce logs yielding 150 tons of pulp per day.

extracting the resinous matter from the wood —in the form of chips— by digestion with sulphur compounds, usually a weak solution of sulphurous acid, about a quarter of which is in the form of bisulphite of lime.[73] A soda chemical process is also employed by some makers. The sulphur used for the production of sulphurous acid is either imported from Sicily or obtained by burning pyrites. Chemical pulp possesses many advantages over mechanical pulp, though its manufacture is necessarily more expensive, and the yield per cord of wood, as compared with the latter, is much less.[74] It has a longer and tougher fibre, and the resinous matter being no longer contained in it, finds uses for qualities of paper for which the mechanical pulp would be unsuitable. The principal markets for pulp are Great Britain, the United States, France, Australia, and Japan. Much of it is used, however, locally for the manufacture of paper. In 1903 the requirements of Great Britain alone amounted to $12,000,000, a little over seven per cent. of her needs.

PAPER.

In many cases the producers of pulp also manufacture it into paper. The principal requisites for the paper industry are a plentiful supply of pulp-wood, good water and an abundance of it, and cheap power; all these can be found in many parts of Canada. The growth in the demand for paper of all kinds, news, wrapping, wall and the finer grades, was one of the features of last century—especially newspaper. The introduction of wood fibre into its manufacture has consequently enabled the supply to keep pace with the demand. The process of manufacture requires no description here; the secretary to a prominent Canadian firm states that or ginally they used rope as a raw material, then straw, which was abandoned for rags, and finally these gave place to chemical and ground wood-pulp. Previous to 1870 no wood whatever was used in the manufacture of paper in this country. Ground wood-pulp was introduced at that time and has since become the filling material of the cheaper grades of paper, being partly pasty and partly fibrous. Up to 1885 the real fibre—the framework of the paper —was supplied by rags. In 1885 sulphite pulp was introduced and has largely replaced rags, except in the higher grades of paper, in which linen is used, and in the very low grades, where straw is employed.[75]

The *Toronto Globe* of March 4th, 1903, in an article on the wood-pulp industry, gives the following statistics, which are of interest:—

	Tons.
Production of mechanical pulp in 1902	152,210
Production of sulphite pulp in 1902	76,735
Production of soda pulp in 1902	9,044

(73) Letter from Mr. Carl Riordan, Merritton, Ont.

(74) One ton of mechanical pulp requires a little over a cord of wood; one ton of chemical pulp requires a little over two cords of wood.

(75) Mines Report, P.Q., 1901.

XIV.—Asbestos and Mica.

Asbestos.

This mineral occurs in large deposits in the "Eastern Townships" of Quebec, where it was first worked in 1878; from 1880 up to the present date the production of asbestos has increased steadily; the output that year is given as 380 tons, while in 1901 over 38,000 tons are recorded in the returns furnished by the producers. The world's supply of asbestos is, for the most part, obtained from Canada, and the Quebec deposits have in the past proved to be the most profitable mineral mined in the province. Thirteen mining companies are at work in this industry, which is principally carried on at Thetford, Lac Noir, and Danville, giving employment to approximately 1,000 men. Asbestos is shipped largely to Great Britain, the United States, Belgium, Germany and France.

Mica.

Another silicate found in Canada is mica, which, though occurring in small quantities, is a not unimportant industry; in Ontario there are several mines and a number of works where splitting, trimming, and sorting the material into saleable sizes is carried on. The Provinces of Ontario and Quebec produce the greater part of the mica used in the manufacture of electrical apparatus in the United States, and also export not inconsiderable quantities to Great Britain. The so-called "amber" mica, or phlogopite, is preferred for this use to other yarieties on account of its superior flexibility and the thinness of the sheets into which it can be split. The mica mines of the General Electric Company in Ontario produce large quantities of mica annually, and the Company have trimming works at Sydenham and Perth. There are also important mica trimming plants in Kingston and Ottawa.[76]

Conclusion.

The new Canadian Niagara Power Company, whose works are in the course of construction at Niagara Falls should give a fresh impetus to the development of industrial chemistry locally. This will be the first company to produce power on the Canadian side of the Falls. A feature in the plant is the size of the generating units, each of which will have a capacity of 10,000 horse-power. They will be more economical than generators of 5,000 horse-hower, will occupy but little more space and their cost will be much less per horse-power in comparison. It is expected that the output of the company will be used principally for Canadian industries and for such public utilities in the Province of Ontario as may be within reach of long-

(76) Letter from Mr. Thos. W. Gibson, Director of Bureau of Mines, Ontario.

distance transmission. The power on the American side is employed by some twenty or thirty firms engaged in such chemical industries as the manufacture of pulp and paper, silver plated goods, chlorate of potash, caustic alkali, salts of tin, carborundum, carbide, graphite, pure metallic lead, "alundum"—another emery substitute,—cereal food-stuffs, nitric acid and composite boards made from wood-pulp and flax-fibre. Judging from all this there should be a large increase in the number of chemical industries in this neighbourhood when the Canadian power station is completed and the current available from the Falls to Toronto.

The subjects that have been considered in this paper do not by any means exhaust the catalogue of chemical industries in Canada. Many important manufactures have, for the reasons mentioned in the opening paragraph, been omitted. A short summary of these will suffice. Matches, for example, constitute an important and necessary article of daily use, and are made in enormous quantities, practically all that are used in Canada being manufactured in the country. Brewing and distilling are carried on extensively also, ale, lager beer, and stout being made, while Canadian rye whisky is known throughout the whole English speaking world even a "Canadian Scotch" is produced at Perth, Ont.; brandy and champagne and other wines are made at Hamilton, Brantford, and Pelee Island, on Lake Erie. Fruit canning is one of the great industries of Wentworth and Essex Counties, Ont.; bacon packing and salmon canning may also be classed among those manufactures requiring the careful supervision of the skilled chemist. To the list may be added explosives of all kinds; blackings, varnishes, japans, lacquers, paints and shellac, foodstuffs and sauces; antitoxines for use in the practice of medicine are made by the Parke Davis Co. at Walkerville. Natural mineral waters are abundant, at St. Catherines, in British Columbia and in Quebec, while manufactured aerated waters are made in mostly all the important towns. The almost universal wearing of india rubber foot coverings during the winter season necessitates the production of large quantities of goods of this sort. Many large factories for this purpose are in existence from which rubber goods of a superior quality emanate; dyeing and calico-printing might also be mentioned as being in a flourishing condition. The attitude of manufacturers towards chemists has of late years been extremely favourable, and many have seen it to be to their advantage to employ men trained in our universities to investigate the processes and materials employed in their particular industries. So far their employment has been amply justified by the results, and it is to be hoped that more may be brought to see the profit to be gained by adopting scientific methods of work. The university man who has specialized in chemistry can assist the manufacturers in this by bringing to bear on the *rationale* of the technical processes the general scientific knowledge which he

has gained during his college course, and his experience of methods of research and manipulation; he can thus materially benefit his employer by improving the quality of his products or enabling him to turn out his goods at a cheaper rate. Let the manufacturer, be he dyer, tanner, pulp-maker, or ironmaster, indicate only that he is willing to find employment for men educated in the higher branches of scientific work, and the universities of the Dominion will supply them. Where chemical processes are used, it is essential for the prosperity of this country that all the available scientific knowledge should be brought to bear on them, in order that they may continue to improve and to develop even more than they have done in the past decade. Canada, with its immense natural resources, and its water power should, in time and with proper management and assistance in the lines indicated, become one of the largest producers of the world's supplies.

In conclusion, I wish to acknowledge the great assistance I received in preparing the previous edition of this paper, from Mr. Fred P. Clappison, B.A., then Fellow in Political Science in the University of Toronto, who gathered together for me from all quarters much of the information required for this short and imperfect account of the chemical industries of the Dominion. In particular his help in connection with the statistics contained in the text and in the appendices was invaluable. Much of what appeared before has been repeated, though many alterations, omissions and additions have been necessary. To the gentlemen who so kindly answered enquiries as to their particular industries and placed valuable material at my disposal I desire also to convey my hearty thanks.

APPENDIX I.

THE IRON ORES OF CANADA.

Nova Scotia.—Magnetites in enormous quantities at Nictaux, in Annapolis County, at Whyhogomah, in Inverness County. Specular and red hæmatite at Nictaux, Stewiacke, Pictou, Antigonish, Guysboro, East Bay, and many other points. Limonite, specular, spathic clay ironstone and hæmatite at Londonderry. Mineral fuel and fluxes are in close proximity throughout the whole district.[77]

Cape Breton.—Extensive deposits of brown hæmatite, magnetite, and spathic ores lying adjacent to the great coal-fields.[78]

New Brunswick.—Magnetite and bog ores. Coalfields at Grand Lake and hardwood throughout the Province.

Province of Quebec.—Very extensive deposits of bog and lake ores, extending from the Province of Ontario to Gaspe, Magnetite deposits especially good at Sherbrooke, Leeds, Sutton, St. Jerome, and in Pontiac County. Hardwood and limestone abundant. Deposits of chrome-ironstone found in 1895 in Coleraine. The "Eastern Townships" obtain iron by dredging in the Lac-a-la-Tortue. Magnetites at Hull, near Ottawa.[79]

Ontario.—Vast deposits from the Ottawa Valley to head of Lake Superior, comprising magnetite, red hæmatite, limonite, specular, and occasional bog ores. The Helen Mine, at Michipicoten, is said to be one of the richest in the world. There are also extensive forests of hardwood, especially suited for the production of charcoal, and fluxes in abundance.[80]

Manitoba.—Magnetite, hæmatite, and bog ore on Lake Winnipeg. Hardwood in adundance.[81]

British Columbia.—Magnetic ores at Texada Island and Cherry Tree Bluff. Coal and wood in plenty. Collieries at Nanaimo (Naval coaling station for H. M.'s ships), Wellington, and Comox. A recent discovery of large deposits of magnetite has been reported in the Boundary Region, which at present mainly finds a use as a flux.[82]

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(77) Nova Scotia Report of Mines, 1901.
(78) Report of Geological Survey.
(79) Mines and Minerals of Quebec, Dept. of Mines.
(80) Bureau of Mines Report, Ontario, 1901.
(81) Geological Survey of Canada, 11th Annual Report.
(82) Geological Survey of Canada, 11th Annual Report.

APPENDIX II.—METALLIC PRODUCTION OF CANADA, 1892-1903.

Metals.	Value, 1892.	Value, 1897.	Value, 1901.	Value, 1902.	Value, 1903. ‡
Pig Iron	637,421 dols	53,796 tons.	1,212,113 dols. †	1,043,007 dols.	707,838 dols.
Copper in Mattes	818,580 " *	1,501,660 dols. *	6,096,581 " †	4,511,383 "	5,728,261 "
Nickel in Mattes	1,399,176 " *	1,399,179 "	4,594,523 " *	5,025,903 "	5,002,204 "
Arsenic	1,000 "	.....	41,676 " †	48,000 "	15,420 "
Gold	907,601 "	6,190,000 "	24,128,503 " †	21,336,667 "	18,834,490 "
Silver	193,441 "	2,613,173 "	3,265,354 " †	2,238,351 "	1,170,779 "
Aluminum	.....	.....	1,000,000 "	1,643,250 "	.....
Lead	49,422 "	1,396,853 "	2,249,387 " †	934,095 "	762,660 "

* Value of metal if refined. † Statistical Year Book, 1903.

‡ Subject to revision, Mr. T. W. Gibson states that the total pig iron and steel produced in Ontario in 1903 amounted to 87,004 tons and 15,229 tons respectively; the whole of Canada yielded, during the same period, 265,418 tons of pig iron and 232,641 tons of steel.

APPENDIX III.‡—IRON AND STEEL PRODUCTION.

Company.	Plant at	Built.	Source of ore.	Employees, 1902.	Output in Tons.				Capacity of Furnaces in tons per day.		Capitalization.
					Pig Iron.			Steel.			
					1892.	1901.	1902.	1901.	1892.	1902.	
											Dols.
Canada Iron Furnace Co...	Midland, Ont....	1899	Ontario.....	..	..	18,948	..	..	..	..	1,000,000
	Radnor, Que.....	..	Quebec.....	..	5,574	31,159	..	..	40	..	..
	Londonderry, N.S.	1887	N.S.....	*	28,052	*	*	*	40,000 per ann.	150	..
Hamilton Steel & Iron Co.....	Hamilton, Ont....	1896	Ontario and U.S.A.....	1,000	† 1,000	..	51,701	9,473	†	..	1,500,000
Nova Scotia Steel and Iron Co....	New Glasgow, N.S.....	..	N.S..	965	29,502	28,407	..	23,916	100	100 pig,	5,000,000
Deseronto IronCo.	Deseronto, Ont ..	..	U.S.A.....	..	..	13,701	..	..	..	100 steel	..
Dominion Steel & Coal Co.....	Sydney, N.S.....	1901	Newfoundland.	6,000	†	27,643	191,259	86,424 (1902)	†	1,000 pig, 800 steel	33,000,000
John MacDougall and Co.....	Drummondville, Que.....	..	Quebec	..	..	793	..	..	6	..	..
Cramp Ontario Steel Co.....	Collingwood, Ont.	1900	Ontario and foreign....	†	..	..	..	..	..	200,000 per ann.	..
Lake Superior Power Co.....	Sault Ste. Marie.	1901	Ontario.....	500	..	..	..	..	†	..	117,000,000

* Not in operation, due to repairs being made. † Not in operation. ‡ Prepared by Mr. F. P. Clappison in 1903, largely from private letters.

APPENDIX IV.*—PORTLAND CEMENT AND PLASTER OF PARIS.

Firm or Company.	Place.	Capital.	Capacity of Plant in barrels per annum.	Output, 1902	Date of Beginning Manufacturing.
		Dols.			
Canadian Cement Co.	Longue Pointe, Que.	200,000	....	....	....
Canadian Portland Cement Co.	Deseronto, Ont.	1,500,000	250,000	250,000	1893
Lakefield "	Lakefield, Ont.	590,000	75,000	75,000	1902
Imperial "	Owen Sound, Ont.	250,000	50,000	50,000	1902
Grey and Bruce "	" "	100,000	30,000	20,000	1902
Owen Sound "	Shallow Lake, Ont.	199,000	100,000	100,000	....
Sun "	Owen Sound, Ont.	500,000	40,000	40,000	1902
National "	Durham, Ont.	1,000,000	300,000	....	1903
Hanover "	Hanover, Ont.	150,000	30,000	30,000	....
		4,399,000			
Albert Manufacturing Co., (Plaster of Paris)	Hillsboro', N.B.	350,000	....	60,000	....

* See Note ‡ in Appendix III.

APPENDIX V.—SUGAR FROM BEET ROOTS.

Company.	Place.	Capital.	Began.	Output.* July 02—July 03	July 03—July 04.	Capacity in tons of beets per day.
		Dols.				
†Wiarton Beet Sugar Co.....	Wiarton, Ont. ...	500,000	1901	1,565,000 lbs.	981,000 lbs.	350
Ontario Sugar Co.....	Berlin, Ont.....	1,000,000	"	6,063,926 "	7,059,695 "	600
‡Dresden Sugar Co.....	Dresden, Ont.....	600,000	"	3,763,987 "	2,094,999 "	600
Wallaceburg Sugar Co.....	Wallaceburg, Ont.	500,000	"	3,606,604 "	4,230,422 "	700
Knight Sugar Co.....	Raymond, N.W.T.	1,000,000	"	.....	.....	300

* Letter from Mr. C. C. James, Deputy Minister of Agriculture, Ontario. † Now closed down. ‡ Removed to Michigan.

THE MEDICAL INSPECTION OF SCHOOL CHILDREN.

By Charles A. Hodgetts, M.D., L.R.C.R. Lond., Secretary of the Provincial Board of Health of Ontario and Deputy Registrar-General.

(*Read 17th December*, 1904).

During the past few years the attention of educationists and health authorities, and incidentally that of the general public has been directed to the great need which exists for medical supervision of school children along special lines. It is not my intention to discuss any of these specialties, for they are simply factors in the one great question which it is proposed to discuss this evening; the adoption of which, would of necessity include the various sub-divisions which up to the present have claimed notice, and the advocacy of which has disturbed educational authorities chiefly from the fact, no doubt, they have felt there was justice in the demand made by each,—but to grant the request of the surgeon dentists for instance, would be to establish a precedent whereby, oculist, aurist, orthopædist, or other specialist, would each expect similar concessions, and the result would be to confuse the teacher and scholar, confound the parents, and in the end result disastrously on educational methods as now in force. For these reasons, together with those of a monetary character, is to be ascribed the fact that up to the present the question of medical inspection and supervision has made but little headway. "The educationist has seen his routine of school work disturbed by the visit of this or that 'specialist,' and attendance become disorganized by reason of the demands made of scholars for the treatment of those referred by this or that particular examiner."

The School Board and the ratepayers have seen the financial difficulties that would have to be met, but they never could see the end. With the growth of the Public School system one important specialty, if I may so term it, has forced itself upon all that there was need for some discrimination in respect to children suffering with or recovering from contagious diseases; hence some temporary measures have been adopted to prevent their spread. But to a student of the question, or to those more intimately connected with either education or sanitation, they cannot be considered as either satisfactory or permanent. It is, however, a move in the right direction, and the only reason that it has thus early found a place in the statute books, is the fact of its appealing di-

rectly to the public of all classes, for contagious diseases know no bounds, and in the past, infection has spread to the homes of the rich and poor alike, carrying with it death, suffering, social inconvenience and both private and public financial losses.

The system of compulsory education in Ontario is founded on "An Act respecting Truancy and Compulsory School Attendance," Chap. 296, R.S.O. 1897, passed in the 54th year of the reign of Queen Victoria. It requires children from eight to fourteen years of age to attend school under penalties laid down in the same Act, which penalties extend to both parents, guardians, and persons with whom a child, between these ages, resides. This Act does, however, exempt from attendance, children suffering from illness or other unavoidable cause, and clearly indicates some discrimination is made in regard to healthy and non-healthy children, although the line drawn is very broad, and notwithstanding its breadth, is somewhat lost in indefiniteness ; for outside of the contagious diseases and illness of an acute or chronic character which incapacitate the child for a longer or shorter period from attending school, there is no differentiation from the medical standpoint of school children, with these exceptions, all except the blind and deaf and dumb are considered physically equal, and it is compulsory for them to attend school until after the completion of the fourteenth year.

True it is that amongst the "duties of teachers" (Cap. 39, 1 Edward VII., sec. 80, sub-secs. 7 and 8) as laid down in the Act, "Assiduous attention" is to be given to the health and comfort of pupils, and admission is to be refused to any pupil affected with, or exposed to smallpox, scarlatina, diphtheria, whooping-cough, measles, mumps, or other contagious disease, until presenting a certificate of a physician or of a health officer, to the effect that danger is passed.

The foregoing is all the provision made under the Educational Act of the province for the medical examination of school children.

Of course the Public Health Act particularly provides, (sec. 103, sub-sec. 1) for the notification to the teacher by the parent of each case of contagious disease within eighteen hours after it has been known to exist, and again (Public Health Act., sec. 104, sub-sec. 1) provides that the local Board of Health is required to notify the head or other master of the school or schools at which any member of the household is in attendance, of the facts ; and again (Public Health Act, sec. 103, sub-sec. 3) requires, that where a teacher has reason to suspect that any pupil has, or that there exists in the house of any pupil any of the contagious diseases "referred to in the section, he shall notify the Medical

Health Officer or local Board of Health," on forms supplied by the school authorities, and authority is given the teacher to (Public Health Act, sec. 103, sub-sec. 3) prevent the attendance of said pupil or pupils until medical evidence of the falsity of the report has been obtained." And to further this, medical inspection was made compulsory in February, 1903, when a series of regulations were passed by the Provincial Board of Health, and approved of by an Order-in-Council, having special reference to diphtheria and scarlet fever, (Regulation re Diphtheria, sec. 8; Re Scarlet Fever, sec. 9) wherein provision was made, "whereby the Medical Health Officer shall personally, or through another physician, cause a daily examination of all the children of the school room, for at least one week from the date of the occurrence of the last case amongst the children, and further, provided that absentees from the same school should be similarly examined at their own homes"; these provisions applied to both diseases, and speaking recently on the Regulations, Dr. Sheard, Medical Health Officer, of Toronto, said: (Sanitary Journal, P.B.H. 1904, page 19) "The Provincial Board of Health last year very properly provided for the personal inspection of every pupil and every absentee, where a case of scarlet fever or diphtheria appeared amongst the pupils of a public school. I will not say that in Toronto that has been done with mathematical exactness, because we have over 30,000 school children to supervise, but I am proud to say the work has been done in the spirit and with the assurance that it would prove satisfactory to all who care to study our methods."

With this review of the Educational and Health requirements as set forth in the Statutes of the Province, it will be noticed that so far as Ontario is concerned, it has in part adopted the principle set forth by Dr. A. Watt Smith, a recent writer on the subject, in the following words :

"The state having made education compulsory, cannot divest itself of the responsibility of taking reasonable precautions to ensure that the conditions under which children are instructed shall not be such as to disseminate infectious diseases or produce physical deterioration." (Physical Deterioration; Its Cause and Cure. A. Watt Smith, page 117). As to how we stand in comparison with other countries and municipalities, will be seen in the following review of the situation :

The first system of medical inspection was that established in the City of Brussels, some thirty years ago. This has from time to time been improved upon ; marked changes being made twelve years ago, these partaking of the nature of a medical control, in addition to an in-

spection with, it is reported, most gratifying results, there being a marked diminution of diseases of all kinds. Of the other cities in Europe, where the system has been adopted, might be mentioned in Germany, Frankfort, Wiesbaden, Dresden and Leipsic, in which latter town with a school population of 67,000, eighteen inspectors are constantly employed.

In the schools of Zurich, Switzerland, a system of medical inspection of both scholars and schools is in force, instituted by the Government and placed under the control of the Central school board. A child undergoes a prescribed examination upon entering school, and here the discrimination begins, and pupils are allocated according to their mental and physical standards. A medical re-examination may be ordered at any time of either pupils or building or both. In addition special provision has been made regarding re-examination of sight and hearing for a number of years, and at the twelfth year an examination is made of the teeth. The Report of Zurich for the years 1899-1900, shows the total number of children to have been 22,912.

Quarantine being imposed on 515 children in the former year, and upon 877 in the latter.

INFECTIOUS DISEASES.

1ST GROUP.—	1899.	1900.
Diphtheria	432	429
Scarlet Fever	132	365
Smallpox	0	1
Measles, Whooping-cough	Not Notifiable.	

2ND GROUP.—

Accidents at school —26 and 21 in the respective years, all of which cases first aid was rendered by a competently instructed teacher.

3RD GROUP.—DEATHS, 27.

Tuberculosis	8
Brain Fever	5
Inflammation of Lungs	3
Accidents	5
Diphtheria	2
Appendicitis	2
Heart Disease	1
Diabetes	1

Of the medical examinations that for eyesight and hearing is made in the Primary Class 1 when the children are of the age of six and seven, and the examination is repeated in the sixth form, when of the age of twelve and thirteen.

An interesting feature of the report for 1899, is that relating to 2,625

children whose school life began in that year, 145 presented evidence of the following ailments :

Mental Weakness (moderate)	21
" " (advanced)	13
Cretins	4
Psychical anomalies of other kinds	2
Imbecile	2
Deaf and Dumb	1
Blind	1
Defective development due to rickets and scrofula	25
" " due to anæmia	3
" " no cause given	30
Spinal Curvature	5
Lameness	2
Defective Speech	10
Weak health, chronic, or due to recent illness	26
	145

A total of 145—or 5.5 per cent.

The most pleasing portion of the report is the statement, "for all these children special provision was made," as thus is indicated a very high standard of co-related medical inspection and educational standards of classification of pupils according to health and physique.

In Great Britain the progress made has been somewhat slow, but the recent report on the investigation of the Inter-departmental Committee on Physical Education, 1904, (Amended Report of the Medical Officer of the late School Board of London, 1904), and the Inter-departmental Committee on Physical Deterioration, will doubtless do much to stimulate the movement in that country. From the Report of the Medical Officer of the late School Board for London, it is quite evident that defunct organization has bequeathed to its successor in charge of the Board Schools of the Metropolis the nucleus of what would be, if the suggestions presented by Dr. Thomas are carried out, an excellent system of inspection.

The work carried on in 1903-04 may be briefly summarized as follows: Staff—One medical officer and two assistants; six oculists; six nurses.

DUTIES OF NURSES.

To visit schools; it was thought that each school could be visited once a quarter, but this was found to be impossible, as some had to be visited frequently.

Sometimes every child in a class is examined, sometimes only one selected by the teacher.

The Head Master takes steps for exclusion on the nurses' report.

They are supplied with names of absentees, and visits are made to the homes.

Their visits to schools are educational to teachers and scholars, while visits to homes are stimulating to parents.

Each nurse has 85 schools under her oversight, with an average attendance of 100,000 children.

The cases treated are unclean heads, ringworm, and favus.

A series of cards are issued to parents, giving information as to treatment, etc.

FIRST CARD.

(Front of card)

PRIVATE NOTICE.

Date.....

Your attention is drawn to the condition of this child's head, which has been noticed in school. The school nurse has examined it, and states that by attention to the directions given on the other side it can be rendered permanently clean within a week. If cleansing is not effected by that time, the child will have to be kept separated from the others in school until the unclean condition is remedied.

(Back of Card).

INSTRUCTIONS FOR CLEANSING HEADS.

Where there are sore places, scabs, or enlarged glands, these will generally get better on removing all lice and nits.

It is possible to effect a cure in about a week.

All hairs with nits and all hair within a quarter of an inch of a sore must be cut off.

The head must be washed and scrubbed daily with paraffin oil, to which an equal quantity of olive may be added. If there are scabs, these when softened should be removed.

Repeat this treatment daily for a week, then weekly until all signs of lice are gone.

Where there is difficulty in keeping a child's head clean, the hair should be worn cut short.

Iron the collar of the clothes with a hot iron.

Caution—Do not use paraffin near a fire or naked light.

SECOND CARD.

(Front of Card).

SCHOOL BOARD FOR LONDON.

Date.....

SECOND WARNING. To the Parents or Guardians of ——————————

A Private Notice regarding the condition of this child's head having been sent you, and as this condition, which should be remedied in a week, is still allowed to persist, the child has now been separated in school as unfit to be in the ordinary class. You are required to take steps to cleanse its head within the next week, failing which the child will be excluded from school and you will be liable to prosecution and fine for not sending it in a fit state to school. The means for cleansing these heads is given on the other side of this card.

(Back of Card. As on First Card).

The result of the use of these instructions issued to eight schools, is the following :

Department.	No. of Children Examined.	Clean.	Verminous.	White Cards.	Red Cards.
Boys	2,492	2,450	42	22	2
Girls	2,422	1,355	1,067	740	183
Infants	2,593	2,207	386	269	55

	Partially Cleansed.	Proposed for Exclusion.	Prosecuted.
Boys	..	2	2
Girls	163	15	2
Infants	99	4	1

The work of inspection for infection in schools, was not begun in London until 1891, in conformity with the Public Health (London) Act of that year, which made it compulsory and in 1903-4, one thousand forms, relating to 3,300 children were received each week.

As an indication of the thoroughness of the work regarding diphtheria, it is stated "that from August, 1903, to March, 1904, it has not been necessary to close any class on account of diphtheria, and the spread of diphtheria in the schools of the Board has been arrested."

The work of the oculists was carried on by a staff of eight, and consists of first the teacher's test of visual acuity and by returning a list of all pupils who had bad vision, that is, V 6-18 or less, and in Standard V or above V 6-12 or less, which are in turn examined by the oculist. The work of the teachers is stated to have been "fairly well" performed, but as many as one-fifth of those returned defective, are afterwards found normal by the specialists.

The system of Special Schools is shown by the data set forth in the following table :

A return from the schedules (884,003) of school children in London, shows that there were known :

	Mentally Defective.	Physically Defective.
In Special Schools	3,295	532
In Ordinary Schools	2,080	717
Out of School	174	863
	5,549 (0.64 p.c.)	2,112 (0.24 p.c.)

from which it is seen that of the 884,003 school children, 5,549 or 0.64 per cent. were mentally defective, and 2,112 or 0.24 per cent. physically defective, and 3,295 of the former and 532 of the latter were provided for in special schools.

And of the children known to be suffering from combined defects,

and known to the teachers, there were ten per cent., which were as follows :

SCHOOLS.	No. of Schools.	No. on Roll.	No. Reported by Teacher as having more than one Defect.	Nature of Additional Defect.				
				Blindness.	Deafness.	Physical.	Mental.	Minor Defects.
Blind.....	10	254	39	..	8	3	21	7
Deaf.....	12	560	57	4	..	7	12	34
Mentally Defective....	67	3,471	464	18	43	177	..	226
Physically Defective....	12	657	15	..	..	...	15	..

It will thus be seen that the work in the metropolis has been moving along on scientific lines in a manner quite typical of English thoroughness.

Coming closer home, it is found that the cities of New York, Philadelphia, Chicago and Boston, have begun the good work, the latter city leading in the initiation of the same, it being the first city in the world to establish a daily system of medical inspection. The work was not begun without some effort on the part of the health authorities, and persisted in for nearly four years.

The work was begun in 1894, on the occasion of an outbreak of diphtheria, and has been continued ever since under the control of the Board of Health. At present the staff of medical inspectors numbers 50, one for each district, who is paid an annual salary of $200, making a daily visit to each of the four schools in his district, with an average attendance of 1,400. The method pursued in this city is as follows :

The teacher sends to a separate room the children who either appear ill, complain of symptoms, or whose parents request it. The medical inspector on his daily round examines these children, keeping a record of each case; and if found to be ill, the child is sent home with a note advising parents as to course of action to be taken. If the case is a contagious one, he notifies the medical health officer, and with this his duties end. If the parents are poor, one of the staff of nurses takes charge of the case. Before the child is permitted to return, however, an examination is made by the inspector. An indication of the extent of the work may be obtained from the fact that in the year 1899, the teachers refused 17,449 pupils, of whom 2,583 or 14.08 per cent. were sent home. Four hundred and sixty-eight or 18 per cent. were suffering from acute infectious diseases and diseases of the throat, mouth, chest or skin.

The work as at present in force in New York City, is fully set forth

in Rules and Regulations herewith appended, and for which I am indebted to Dr. John J. Cronin, Assistant Chief Medical Inspector. Regarding the character and volume of work accomplished, the reports of the medical inspectors and nurses, for the borough of Manhattan, for the year 1903 are as follows :

MEDICAL INSPECTORS' REPORT FOR YEAR 1903.

BOROUGH OF MANHATTAN.

No. of school days	188
No. of schools visited	263
No. of visits to schools	62,298
Average daily attendance	287,592
No. of examinations	6,236,336
No. of exclusions	41,826
Measles	168
Diphtheria	510
Scarlet Fever	45
Pertussis	201
Contagious Eye Disease	25,264
Pediculosis	8,676
Chicken Pox	673
Skin Diseases (contagious)	1,561
Miscellaneous (acute coryza, tonsilitis)	4,728

NURSES' REPORT FOR YEAR 1903.

BOROUGH OF MANHATTAN.

No. of visits to schools	11,098
No. of visits to tenements	12,891
No. of miscellaneous visits	293
No of treatments—	
Pediculosis	156,886
Contagious eye diseases	106,257
Eczema	3,379
Ring worm	8,498
Scabies	335
Miscellaneous	10,438
Total cases	285,793

The system was initiated in 1897, and there are now 150 inspectors each having 5,000 children under supervision. The visits are made daily before 10 a.m. when children isolated by the principal are inspected. On the occasion of the routine weekly inspection, the pupils are marched past the inspector, who examines eyes, ears, nose, mouth, hair, etc. Suspicious cases are ordered to the office and re-examined, and if found defective, an exclusion card is sent to parents in sealed envelopes containing instructions and if found necessary, the case is visited by one of the staff of nurses.

The review of the work in other countries has perhaps been a little lengthy, but in no other way could an intelligent idea be formed of the

character and extent of the practice, and criticisms made or conclusions arrived at.

In considering the introduction of the system in this province, the question naturally arises, what are the objections that could be raised, and what weight they carry in preventing its early adoption? They may be considered under two classes: those of the parent and of the teacher. To the former it may appear unnecessary, chiefly for the reason that all the dangers and disadvantages surrounding modern school life, together with their far-reaching effect upon the health and physique of the future men and women of our country, are not apparent to them, hence a campaign of education among the parents is necessary, and even when seized of all the facts, objections will still be strong on the ground of increased cost, hence extra school rates. These must be met by statements showing the financial losses to the state, both on physical, mental, and hygienic grounds, as also the great financial losses incurred by individuals and municipalities, for medical treatment of disease, not to mention the loss and suffering caused by death.

The objections raised by educationists and educational authorities are more difficult to deal with, but fortunately the pendulum of opinion is swinging in the right direction, and the prominent men in all civilized countries are strong advocates of this system. There can be no gainsaying the fact that the duties of the teacher and principal will be increased, and it will require the teacher to devote some portion of his studies to the subject of hygiene, as related to the child and child-life, and diseases incident thereto ; but on the other hand his position is strengthened in all matters covered by this system, in many of which he has had to rely on his own opinions, and often comes to conclusions and adopts rules, which under the system of medical inspection is not the case.

The objection that there may be clashing with the health authorities is answered by pointing out that the system in force in the cities of the United States, is under the care of the same and not controlled by a new department, and similarly any clashing with the medical profession is obviated by the duties of the inspectors being first selective and advisory, and lastly prohibitive as regards school attendance, and only in cases of poverty is assistance rendered or aid given by the medical staff or visiting nurses.

It may further be advanced as an objection, that great difficulties exist in rural municipalities for the effective carrying on of the work. In the cities and towns the system is practicable, but outside of these it cannot be carried out successfully. Certainly under the present con-

ditions of the Public Health Act, such is to a large degree true, but reconstruct it by adopting a system of county or district health officers in lieu of the very unsatisfactory one now in force, and trained medical officers would be employed by counties or districts to superintend and manage health affairs generally, devoting all their time to the duties of the office. With such a system in force I am satisfied the medical inspection of rural schools in this province is a possibility, and the change can be brought about with but slight additional expense to the ratepayer.

Having indicated the objections which may be made to the system, it may be of interest to briefly touch upon some of the advantages, for they are many and of such deep import to the individual and the state, that to consider them at any length would unduly extend this already lengthy paper. But time and opportunity may be afforded elsewhere for presentation of the same. Here, at least a number of the more importtant will be mentioned.

As at present the provision for the classification of children is for gross defects or abnormal types, such as imbeciles, idiots, epileptics, blind and deaf and dumb, and for those of somewhat of a criminal type for Industrial schools, so medical inspection will provide for the discrimination of those mentally and physically fit as compared to those unfit from minor or major defects, some of which are preventable if treated immediately, but if neglected are permanent in character, scarring for ever the life of the individual. These defects in child-life exist now, but the teacher cannot be expected to discover them as the signs present are only to be detected by a medically trained person, and in this manner very material assistance will be rendered to teachers generally. An interesting example of this fact is to be found in the Report of the Royal Commission on Physical Training, (Scotland), see page, 100, where it was found as a result of 40,000 observations, "that the large number of serious and minor diseases directly and indirectly affecting mental and physical efficiency, constitutes an overwhelming case for a medical inspection of school children."

The system will enable the parents to secure for their children that medical treatment of which, up to the date of the medical inspection, they were entirely ignorant of its requirement. Further, it will secure to the referred pupils that attention to detail in their course of study which through ignorance in the past, had not been given ; the burden of study will be fitted to the back, whereas heretofore all backs have been considered equally strong. Thus school education will be made to help, not hinder development in later adult life, and will not overtax the child brain, but in like manner aid its development during this later period.

Knowledge will be acquired without loss of elasticity in mind or of wasting in body; the lesson will then have been learned and acted upon, that "the physical equilibrium is essential to the highest organization of character."

To sum up, medical inspection will materially help the improvement and education of this young nation of Canada. The child when he comes under the influence of the school law, "has already lived through a long and adventurous history. He is born of parents of a given race, of a given community, themselves featured and developed by incalculable perplexities of influence. He has inherited certain predispositions of his parents. He may have been affected by parental diseases. He may have suffered in his life before birth. He has through many critical moments struggled into individual existence. He has survived all the serious vicissitudes of his first week, his first month, his first year, his first five years. He has learned to walk, to talk, to assert his place in the mimic community of children. He has acquired individual habits. He has laid the basis of morals. He has come to some sense of individuality in the family. He has even acquired the rudiments of citizenship. He has at last made the great transition from the home to the school, from his cradle community to the community of strangers, from the soft nurture of family sentiment to the realities of discipline. At every stage in his history he has acquired something that his whole life will not extirpate. He has been touched with some diseases that make him safe against them forever. He has found his organs fit enough to carry him thus far. He is now about to enter a much vaster struggle, a more remorseless ordeal, a life full of greater stresses, energies and dangers." One too which he is forced into by the state. Is it not therefore important and essential for the state to search out the pre-school life influences, and to study their bearings on the modifications it is necessary to make in the course of study of each particular child, and the educational system culminates in the production of the state evolved man or woman, upon whose completeness devolves the growth of the people as a nation?

What then are the principles that should be adopted in a system of medical inspection, one applicable to this province? This is a question which I think should be considered by a special committee or commission appointed by the Government for the purpose, and the personnel of which should be representative of both the teaching and medical professions, which committee or commission should report at an early date. My opinion is, that the system should be under the control of the health authorities and be conducted by medical men acting along definite lines, the immediate object being to ascertain the fitness or otherwise of each

child. The examination should be full and detailed; the information required should be tabulated as briefly as possible. The first examination will of necessity be the most tedious in making; it should include an anthropometric summary of all school children, having for its object the taking periodically of measurements, such to include address, occupation and nationality of parents, personal appearance, height, chest-girth; (*a*) maximum weight, length, breadth, and height of head, breadth of shoulders and hips; (*b*) minimum weight, length, breadth, and height of head, breadth of shoulders and hips; using test by (1) Sneller's type, (2) by colours.

Again there should be a report on the condition of ears, nose and throat and teeth, and defects in speech such as stammering. Deformations of all kinds should be noted, also diseases both of the infectious and non-infectious groups and other special observations which the examiner may deem of import.

In addition to this primary examination, a record of which should be filed, there should be a daily inspection of all cases referred by the teacher or head master, this being done by preference each morning, and each week all the pupils of a district to which an inspector is assigned, should be personally examined by him. These inspections are for the purpose of either checking the spread of contagious diseases, or permitting of the early treatment of what would be more serious cases of illness.

Those pupils found unfit at the time of their primary examination should necessarily be objects of more careful medical examination, although they will be decidedly in the minority of the total number examined, but their ranks will be increased from year to year by those presenting either physical or mental deficiency. To this class the inspector will naturally include an oversight of their course of study, both physical and mental, thereby presenting opportunities for correction or adjustment.

In addition to the medical inspector, it will be found necessary in some municipalities, such for instance as cities, to establish a system of nursing inspection, the offices of which will naturally be extended to those in poorer circumstances. This branch will be found of great assistance in the preventing of the spread of contagious diseases of the acute type, and also prevent the spread of those of parasitic origin, and will very materially shorten the period for which many cases of the latter kind would be kept at home.

The system of medical inspection should be extended to an over-

sight of the sanitary condition of school-rooms and school buildings, the regulation of school hours, the seating of scholars, the type of text-books and many other points of minor importance, all of which, however, have a bearing upon child-life.

In conclusion I would suggest the issuing to both teachers and scholars of a series of pamphlets by the Minister of Education on the approval of the Provincial Board of Health dealing with the different matters relating to personal and school hygiene, the same to take the place of text-books.

APPENDIX.

RULES AND REGULATIONS FOR MEDICAL INSPECTION OF SCHOOLS, NEW YORK BOARD OF HEALTH.

Medical inspection of schools shall be accomplished by (1) medical inspectors ; (2) school nurses.

The duties of the medical inspectors will be: (1) Morning inspection; (2) weekly routine inspection ; (3) visitation of absentees ; (4) vaccinating (in districts and special).

MORNING INSPECTION.

Inspectors are required to visit the schools to which they are assigned or morning work, before 10 a.m., each school day. All public schools must be visited before 10 a.m.

They are to examine each child that has been isolated by the teachers as a possible source of contagion, and all those absent from school for a few days for no known reason, and all excluded children; and exclude from school attendance anyone affected with, or showing symptoms of, an infectious or contagious disease.

The following affections should be excluded from the schools without any delay, and the patients sent to their homes, viz.: Measles, diphtheria, scarlet fever, whooping cough, mumps, chicken pox, and any acute catarrhal affections of the eyes, nose or throat.

In a case of suspected smallpox—a very remote possibility—the patient should be kept at the school, isolated in a suitable room, and the Department of Health notified at once.

Each pupil who is excluded from school is to be furnished with a card on which is noted the name, age, and address of the pupil; the number and situation of the school, and the reason for exclusion. These cards are to be made out by the Inspector, and submitted to the principal of the school or to anyone whom the principal may designate, with a proper supply of envelopes. The principal will have a record made of the names, etc., for his or her own convenience, and will then have each card sealed in an envelope and taken home by the pupil excluded.

Children afflicted with pediculosis, contagious eye or skin diseases, or pulmonary tuberculosis, may be allowed to return to their classes temporarily. Exclusion cards are to be made out in the usual way and

submitted to the principal; who will cause these children to be excluded at the next occurring recess. Measles, scarlet fever, smallpox, are to be reported forthwith to the Central Office by telephone. Every throat inflammation or nasal discharge is to be cultured and duplicate culture slip forwarded. Each culture tube should be wrapped in its corresponding blanks and fastened and placed in collecting station before 2 p.m. on the date that it is taken.

WEEKLY EXAMINATION OF ALL CHILDREN.

Once each week the inspector will make a round of all the classrooms, and examine the eyelids, throat, hair and skin of each pupil, individually. Any child suspected of having measles, scarlet fever, whooping cough, chicken pox, diphtheria or mumps, or having any acute catarrhal affection of the eye, nose or throat, is to be sent from the classroom at once for more careful examination in the room assigned to the inspector. If excluded, a properly filled out exclusion card is given, sealed in an envelope and child sent home at once. Principal must be notified of all such exclusions.

The name of each child found with any contagious disease, of whatever degree, is to be entered on the index card for that particular class where the child is found. All details required by the index cards must be entirely filled out. In cases of pediculosis, trachoma, acute conjunctivitis, scabies, ringworm, impetigo, favus, molluscum contagiosum, the name of the child is entered on class index card, and the date filled in on which the child was "ordered under treatment." In these cases, the children are given forty-eight hours to get under treatment. Whenever they are under treatment within this time, the card is checked up with the date under "under treatment," and the child allowed to return to the class. If children are not under treatment in forty-eight hours, they are excluded forthwith and checked up under "excluded."

When the child returns for readmission, it is to be seen by the inspector during his morning inspection and admitted, if under treatment. If not, exclusion is to be continued. Repeated refusals to go under treatment should be reported at the Central Office, with all facts of the case. When re-admitted, check up on index cards under "re-admitted." In cases of trachoma, indicate treatment under "remarks" column, such as operation, etc.

If suspected diphtheria has been excluded and culture shows no K. L. B., the inspector must visit the case at home, and direct the return of the child to school if no new symptoms have developed.

Cases of mumps that have been excluded may be re-admitted by Inspector in charge of the school.

The second day following, the medical inspector will return to those classes in which he had ordered children under treatment 48 hours previously. He shall call for the children ordered under treatment in that class, and check them on index card as under treatment or exclude them as the occasion may require. When all of these cases have been attended to, proceed with regular routine work of other classes in the school.

A daily report for each school assigned to the inspector must be forwarded each school day by the inspector in charge to the Central Office, so as that it shall be received at Central Office not later than 9 a.m. the day following.

In his report must be stated the number examined in morning and routine inspection and the total ; also the number excluded, giving the name, age, address and reason for exclusion. The report must be properly backed and signed.

These daily reports must be made in duplicate as regards the name, age, residence, date, and reason for exclusion of all excluded children. One is to be placed on file at the school so that it may be referred to by the school nurse or principal or other authorized person, and the other, properly filled out, to be forwarded to the Central Office.

Class index cards must be left at the respective schools and kept on file, that they may be referred to by any authorized person.

Afternoon classes are to be inspected as per instructions above. "Morning inspections" refer to the call to see if any suspicious cases have been isolated by the teacher.

Class index cards for afternoon classes are to be marked p.m. class. Each inspector shall be held responsible for the proper condition of health in his schools and must require that each case indexed for disease shall continue under treatment until the condition requiring treatment is cured.

Under no circumstance will an inspector treat any disease. He should refer cases of trachoma to the Gouverneur Hospital, and pediculosis, acute conjunctivitis, scabies, ringworm, impetigo, favus, molluscum contagiosum, are referred to the school nurse assigned to the school.

All cases sent to the nurse must have a card on which is written the code number of disease for which the child is sent to the nurse.

When, in the opinion of the school nurse, the child is cured, the

inspector will examine the case and under "Remarks," check date when cured. If, in his opinion, more treatment is necessary, the case is to be returned to the nurse with card and code number of disease, requesting further treatment.

Under no circumstances or provocation shall an inspector carry on any controversy with principals or teachers. Any instance of irregularity, lack of co-operation, interference with the work of the inspector as ordered by the Department, by principals or teachers, must be forwarded to the Assistant Chief Medical Inspector in writing for adjustment.

Whenever any difference of opinion arises between an inspector and a physician not connected with the Department, concerning the propriety of excluding a case of eye disease, the patient is to be sent to the Central Office between the hours of 12 noon and 1 p.m., on any school day for examination by an oculist.

Cases of measles or scarlet fever are to be reported to the Department by telephone. They will be visited at their homes by diagnosticians, for the purpose of confirming the diagnosis. Cultures are to be taken for all cases excluded for throat affections.

Cases of chicken pox are to be reported to the Department by mail. They will be visited by the district medical inspector within 24 hours for the purpose of confirming the diagnosis. Children excluded from school on account of measles, scarlet fever, chicken pox, smallpox, or diphtheria, must not be allowed to resume attendance until they have received a written certificate from the district medical inspector that the rooms occupied by those cases are free from contagious disease, and that the children are ready to return to school.

The inspectors shall ascertain from the principals and teachers of their schools, the name and address of all absentees who may possibly have contagious disease in their families, where notification has not been sent to the school by the Department of Health, and shall visit such absentees on the day the list is given them and forward each day special absentee report with school report. This list must be asked for daily.

Vaccinations are to be performed as directed by the Central Office. Primary vaccination cards are to be forwarded to Central Office, giving name, age, residence, date of vaccination, and signed by the inspector.

If by reason of illness or other cause, an inspector is unable to report at his schools, he must notify the Department of Health at once by tele-

phone, telegram or special messenger. This notification must be followed within three hours, by a written application for leave of absence. When the inspector returns to duty after illness or other cause of absence, he must report in person at the Department, make out a second written application for leave of absence, stating definitely the dates during which he was away from duty and attach thereto a certificate from his attending physician.

Every Saturday, at 9 a.m., the medical school inspectors shall report at the Central Office in person.

Respectfully yours,

JOHN J. CRONIN, M.D.,

Assistant Chief Medical Inspector.

DUTIES OF SCHOOL NURSES.

1. The school nurse shall receive from the supervising nurse the following information : (a) the schools in which she is to perform her duties ; (b) the hours for visiting each school ; (c) to whom she shall report in each school.

2. The school nurse on entering a school shall report (a) to the principal of the school, and from the principal obtain a place in which to work ; (b) to the medical inspector in charge of school, and arrange with the medical inspector a method for receiving daily report of cases to be visited or treated.

3. The nurse shall keep a record, in a book kept for the purpose, of her time of entering and leaving schools.

4. On arriving at school each day, the school nurse shall report to the principal or the principal's representative.

5. She shall record in a book provided for the purpose, the name, age, address, disease, and treatment of each child attended in school. A separate record shall be kept of all excluded children and children to be visited.

6. The names of excluded children will be obtained each day from the daily list left by the medical inspector in the clerk's desk.

7. All children excluded shall be visited by the school nurses at their homes, if they do not return at the time specified by the medical inspector, except that children excluded for measles, scarlet fever, diphtheria, varicella, peritussis, mumps, shall not be visited by the school nurse.

8. Revisits must be made, if necessary.

9. In visiting homes, instruction shall be given by the school nurse to the mothers, for cleansing heads, and where necessary, the instructions may be practically demonstrated. Whenever necessary, children should be urged to go to a doctor or dispensary for treatment, when they are excluded for diseases that cannot be treated at home by the nurse, or parents.

10. Cases of trachoma shall never be treated by the nurse. All cases of trachoma should be referred and urged to go for treatment to the Department Eye Hospital, at Gouverneur Street and East River.

11. Notes shall not in any case be sent to parents. School nurses shall visit homes whenever instruction is necessary.

12. If by reason of illness or other cause the school nurse is unable to attend to her duties, she must notify the Department of Health at once by telephone, telegram, or special messenger. This notification must be followed within three hours by a written application for leave of absence. When the school nurse is ready to return to duty after leave of absence on account of illness or other cause, she must report in person to the chief inspector at the Department of Health, make out a second written application for leave of absence, stating definitely the dates during which she was away from duty, and in case of absence on account of illness, attach to the second application a certificate from her attending physician.

Department of Health, New York City.

INSTRUCTIONS TO NURSES.

The following methods will hereafter be used in treating children sent to the nurse by the medical inspector of schools :

Pediculosis—Saturate head and hair with equal parts kerosene and sweet oil, next day wash with solution of Potassium Carbonate (one teaspoonful to one quart of water) followed by soap and water. To remove "nits," use hot vinegar.

Favus. Ringworm of Scalp—Mild cases: Scrub with Tr. Green Soap, epilate, cover with Flexible Collodion. Severe cases: Scrub with Tr. Green Soap, epilate, paint with Tr. Iodine and cover with Flexible Collodion.

Ringworm of Face and Body—Wash with Tr. Green Soap and cover with Flexible Collodion.

Scabies—Scrub with Tr. Green Soap, apply Sulphur Ointment.

Impetigo—Remove crusts with Tr. Green Soap, apply White Precipitate Ointment (Ammon. Hydrarg).

Molluscum Contagiosum—Express contents, apply Tr. Iodine on cotton toothpick probe.

Conjunctivitis—Irrigate with solution of Boric Acid.

ORGANIZATION OF SCHOOL NURSING SERVICE.

1. Applicants for the position of "School Nurse" shall be interviewed and their credentials obtained and investigated by the Supervising Nurse, who shall forward the result of this investigation and her recommendations to the Board of Health.

2. All school nurses shall be responsible in disciplinary matters, in all details outside of medical orders, to the Supervising Nurse.

3. The Supervising Nurse shall be responsible for the general management of the "School Nursing Service." She shall make a monthly report, in writing, of the work of each nurse, which shall contain a record of each nurse's practical ability, punctuality, tact, etc.

4. Weekly reports from nurses to be handed in to the Supervising Nurse, and by her examined, corrected, and transmitted to the Chief Inspector. Nurses may be summoned, personally, to the Department of Health upon order of the Chief Inspector.

5. Nurses shall have the right of appeal to the Chief Inspector in questions of difficulty which cannot be settled by the Supervising Nurse. Such complaints shall be made in writing, and shall give all facts and data.

DUTIES OF THE SUPERVISING NURSE.

1. She shall have entire charge of all the nurses, and be responsible for the efficiency and character of the work performed by each nurse, in all boroughs of the city.

2. She shall make all necessary arrangements for the beginning of the nurse's work in the schools.

3. She shall see that the necessary supplies are provided for the nurse at each school.

4. She shall regulate the proper amount of work for each nurse,

making whatever changes are necessary. The Chief Inspector is to be notified at once of any change in schedule.

5. She should inspect the work of each nurse, as far as possible, or necessary, about once a week.

6. She shall see that a register is kept of the time spent in each school by the nurse thereto assigned.

7. She shall instruct the nurses that they must treat nothing but minor contagious diseases, except that they may render assistance in any case of accident.

THE CAUSES OF FAMINES IN INDIA.

By Rev. J. T. Sunderland, M.A.

(*Read 3rd December*, 1904).

The famines of India are among the most startling phenomena of our time. They seem to be steadily increasing both in frequency and severity. During the last forty years of the nineteenth century—from 1860 to 1900—India was smitten by not fewer than ten famines of great magnitude, causing a loss of life that has been conservatively estimated at 15,000,000.* These figures are appalling. Such a condition of things naturally awakens the sympathy of the world. But it ought to do more. It ought to compel a far more careful inquiry than has yet been made into the causes of these famines, with a view to ascertaining whether the causes can be removed or not, and thus whether such scourges as now visit India with ever growing frequency are not preventable.

It is perhaps generally believed that famines in India are unavoidable, and that the causes which produce them are two, namely, failure of the periodic rains, and over-population. Let us see whether this belief is well founded.

Rain–Failure.

How serious is the failure of rains in India? Need it bring famine?

India is a large country. Out of its vast area (if we include Burmah) thirty-six states as large as the great state of New York might be carved. Within this area there is a great variety of climate, of soil, of amount of rain-fall, and therefore of productivity. The great monsoon rains which supply most of the moisture for India vary greatly from year to year. These rains of course man cannot control. If they are abundant over the whole land, the whole land has abundant crops. If they fail in parts, those parts have agricultural scarcity.

Three things, however, should be remembered. One is, there is never failure of water everywhere. When drought is severest in certain

* This is the very careful and moderate estimate of Mr. R. C. Dutt, C.I.E., author of the "Economic History of India," based on the most exact records obtainable, official and other. (See his "Indian Famines; Their Causes and Cure") London, P. S. King & Co., 1901 pages 1-3. Also see his larger work, "Famines in India," Kegan Paul & Co., 1900. Other estimates are much higher than this of Mr. Dutt, rising to 25,000,000 and even to 30,000,000.

The Bombay correspondent of the London *Lancet*, the leading medical journal in Great Britain, estimates the number of deaths from famine in the last ten years of the century at 10,000,000 (*The Lancet*, June 1901).

sections, other sections have plenty. The second is, India is a land where there is much irrigation, and easily might be much more; and, wherever there is irrigation, failure of rain does not mean failure of crops. The third thing to be remembered is that transportation is easy between all parts of the land. On two sides is the sea. Navigable rivers and canals penetrate large sections. There is no extended area that does not have its railway. Thus food can readily be conveyed from areas of abundance to areas of scarcity. Under these circumstances it is easy to see that even if we admit to the fullest extent the uncertainty of rains in many large areas of India, it does not follow that there need be famine or loss of life in those areas.

It should not be forgotten that the aggregate of rainfall in India, taking the country as a whole, is large. The heaviest recorded precipitation in the world is found here. The only difficulties are those of storage and distribution. And even in the matter of distribution, India's mountains and rivers furnish such facilities as are seen in few other lands. Note her great mountain chains. Parallel with the coast of the Arabian Sea and the Bay of Bengal extend the Western and Eastern Ghats. Running across the peninsula are the Vindhya and the Satpura ranges. Stretching along the whole north for a distance of more than 1,500 miles are the mighty Himalayas, the highest mountain range, and perhaps the greatest reservoir of snow and rain, in the world. In the Himalayas rise the three great Indian rivers, the Indus, the Brahmaputra and the Ganges, each of which carries to the sea a volume of water that is enormous. All the other mountain ranges also give birth to important streams. Thus India has two sources of water supply on a large scale; one is her rains, which fall in abundance in most parts; the other her mountains, which send down numerous and in some cases vast rivers, to afford opportunities for almost limitless irrigation, as they travel on their long journeys to the sea. As a result the agricultural possibilities of India are greater than those of almost any other country in the world.

IRRIGATION.

Wherever in India water can be obtained for irrigation, whether from rivers or storage reservoirs or wells, there crops are certain. From time immemorial there has been much irrigation. Since India came under the control of the British, the government has interested itself considerably in promoting irrigation works. But unfortunately, it has also been guilty of much neglect. Not only have important new opportunities for supplying extensive areas with water for irrigation purposes been allowed to go unimproved, but irrigation canals and storage reservoirs which were

constructed in earlier times have been permitted, in not a few cases, to fall into decay. Within recent years there has been a change for the better. Some extensive irrigation schemes have been carried out, as the Chenab Canal in the Punjab, which irrigates 2,000,000 acres, the Jhelum canal which irrigates 300,000, and the great Ganges canals. According to the Scott-Moncrieff Commission (Report of 1903) the government has irrigated in all some 21,500,000 acres.* But very large areas capable of irrigation still remain neglected. One wonders all the more at the slowness with which the government moves, when one bears in mind that most of the money which it has spent on its irrigation works pays an interest of fully seven per cent., besides accomplishing untold good in saving human life. It is difficult to avoid asking, why should so many other things be allowed to take precedence over irrigation? The amount of water going to waste every year which might be saved is enormous. Great numbers of new canals ought to be dug; old canals ought to be re-opened; canals now in use ought to be deepened and widened. In regions where water cannot be obtained for the supply of canals, thousands of new wells ought to be sunk, and many old wells ought to be deepened. Hundreds of new tanks and reservoirs and small lakes ought to be constructed, and hundreds of old ones enlarged, so as to store for use the vast quantities of surface water which now run to waste. It is generally supposed that famine years in India are always years of very light rain-fall. This is a great mistake; they are often years of very heavy rain-fall. The only trouble is the rain comes too early, too late, or too much at a time, and *is not stored*. Compare India with England. The greater part of England has an average annual rain-fall of under 40 inches. A large area in England, and all the more important agricultural districts in Scotland, have an average rain-fall not exceeding thirty inches. It is calculated that in any country an average of twenty inches properly distributed throughout the year, insures reliable agriculture without irrigation. But the rain-fall in India in many years when famine is severest, rises far above these figures. The trouble is, the water is allowed to go to waste for want of proper storage; hence there is disaster. The year of the great Madras famine of 1877 was one with the enormous rain-fall of sixty-six inches. In the year of the Orissa famine (1865-66) the rain fall was sixty inches. In the Bombay famine of 1876 the rain-fall of the year was fifty inches. In the famine of 1896-97 in the Central Provinces, the record of the two years was fifty-two inches and forty-two inches. In the great famine year, 1900, the average rain-fall record in the parts of India where the famine was most severe was (I omit fractions) North-Western Provinces, thirty-two inches; Punjab, eighteen inches; Central Provinces, fifty-two inches; Central

* The total irrigated area in India in 1900 was 31,544,000 acres.

India, thirty-six inches; Rajputana, twenty inches; Berar, thirty-one inches; Bombay, forty inches. Thus we see that in most cases the real lack is not rain, it is *storage*. Says Major Philip B. Phipson (and few persons can speak with fuller knowledge): "The water supply of India is ample for all requirements, it only requiring to be diverted from her rivers, stored up from her rain-fall, and distributed over her fields, to secure such an abundance as shall leave no single human being wanting it."*

PLENTY OF FOOD EVEN IN FAMINE YEARS.

But even under present conditions, with irrigation as imperfectly developed as it is now, and with so large a part of the water that falls wasted, India is one of the greatest of food-producing lands. No matter how severe the drought may be in some parts, there is never a time when India as a whole does not contain food enough for all her people. Indeed, in her worst famine years she exports food. In her worst famine years there is plenty of food to be obtained, and in the famine areas themselves, and generally at moderate prices, for those who have money to buy with. This the Famine Commissioners themselves have told us. To show that the starvation of the people is caused not by lack of food in the land, but by their own poverty, I need only point to the fact that a large part of the life-saving work carried on by the government in connection with the recent Indian famines, has taken the form, not of furnishing food (there was no need for that), but of supplying the starving people with a little money (a penny or so a day to each) wherewith to purchase the food, which was all the while offered in abundance by the dealers. Thus it becomes evident that if we would discover the causes of the periodic starvation of such vast numbers of the Indian people, we must look deeper than the mere failure of the rains.

THE THEORY OF OVER-POPULATION.

Are the famines of India produced by over-population?

A very little study of the facts furnishes an answer to this question. The population of India is not so dense as in a number of the States of Europe, which are prosperous, which have no difficulty in supporting their people, and in which famines are never dreamed of. Nor is the birth rate high in India. It is less than in England, and much less than in Germany and several other Continental countries. Indeed, it is seventy-five per 1,000 lower than the average birth-rate of all Europe. India is not over-populated. As already pointed out, even under present condi-

* "Indian Poverty and Indian Famines," p. 52. Republished from the *Asiatic Quarterly* by Wm. Hutchinson & Co., London, 1903

tions she produces more than food enough for all her people. If her agricultural possibilities were properly developed, she could easily support a greatly increased population. There are enormous areas of waste land that ought to be subdued and brought under cultivation. In the Province of Assam alone there are several millions of acres of such land, now wholly unoccupied largely because of unfavourable health conditions. Sir Henry Cotton, late Chief Commissioner of Assam, who has made a careful study of the matter, urges that all that is necessary to make these great areas fit for habitation and cultivation, is proper drainage. Nor is Assam peculiar in possessing unoccupied lands. The Hon. D. M. Hamilton in his speech in the Viceroy's Council on the Indian Budget of 1904, declared that there are a hundred million acres of cultivable waste land still available in India.* In these very large reclaimable areas, and in the opportunities for the extension of irrigation already referred to, we have ample provision for any possible increase of population in India for a hundred years.

But beyond these there is another resource greater still. Indian agriculture is for the most part primitive and superficial. The Indian ryot, or small farmer, is industrious and faithful, but he tills his soil according to methods that are two or three thousand years old. The result is he raises crops which are only a fraction of what they might be under improved methods of tillage. Long ago Sir James Caird, urging upon the Indian government the importance of promoting improved methods of agriculture, called attention to the fact that a single additional bushel per acre raised by the ryot would mean food for another 22,000,000 of people. But the addition of a bushel an acre is only the mere beginning of what might be done. Mr. A. O. Hume, long connected officially with the agriculture of India, declared that "with proper manuring and proper tillage, every acre, broadly speaking, of the land in the country can be made to yield thirty, fifty or seventy per cent. more of every kind of crop than it at present produces." Here is a resource that is practically inexhaustible. Add this to the others named, and we see at once that the suggestion that population is outstripping agricultural possibilities, and therefore that famines are inevitable, becomes hardly better than ludicrous.

THE POVERTY OF THE PEOPLE.

What then is the cause of the famines in India? The answer to this question has been already suggested, and it becomes increasingly clear the more we investigate. The real cause of Indian famines is the extreme poverty of the people,—a poverty so severe that it keeps a majority of

* Indian statistical tables of the year 1897-8 give the amount of cultivable land at present, waste or unused, as 106,539,103 acres.

all on the very verge of suffering even in years of plenty, and prevents them from laying up anything to tide them over years of scarcity. If their condition were such that in good years they could get a little ahead, then when the bad years came they could draw on that as a resource. This would not save them from hardship, but it would save them from starvation. But as things are, the vast majority have no such resource. Even in the best years they have all they can do to live and support their families in the barest possible way, without laying by a rupee for a rainy day. The result is, when their crops fail, they are helpless. For a while they manage to keep the wolf of famine from the door by selling their cow, if they have one, their plough bullock, and such bits of simple furniture from their poor dwellings, or such cooking utensils or such articles of clothing as they can find a purchaser for at any price. Then, when the last thing is gone that can be exchanged for even an anna or a handful of grain, there is nothing left for them except to sit down in their desolate homes, or wander out into the fields and die. This is the history of thousands and millions of the Indian people in times of famine. If the poor sufferers are so fortunate as to be received by the government at the famine relief works, where, in return for exacting labour in breaking stone or something of the kind, they are supplied with means to buy sufficient food to sustain life, then the hardiest of them survive until the rains come, when, with depleted strength, they go back to their stripped homes, and, barehanded, begin as best they can the task of raising a new crop and supporting such members of their families as may be left. Here we have the real cause of famines in India. As an eminent writer on Indian economics has said, famines in India are "only the exceptional aggravation of a normal misery."

The truth is, the poverty of India is something that we can have little conception of, unless we have actually seen it, as alas! I have. Lest I should seem to exaggerate, let me cite some facts and figures from authorities that cannot be questioned.

Sir William Hunter, one of the most candid of writers, the distinguished historian of India, and for many years director-general of Indian statistics, declared that 40,000,000 of the people of India are in the condition seldom or never to be able fully to satisfy their cravings of hunger. Lord Lawrence, a Governor-General of India, said in 1864, that "the mass of the people were so miserably poor that they had barely the means of subsistence" even in years when there was no drought. Mr. A. O. Hume, Secretary to the Government of India in the Agricultural Department, wrote in 1880: "Except in very good seasons, multitudes, for months in every year, cannot get sufficient food for themselves and their families."

Sir Auckland Colvin, a Finance Minister of India, describes the tax-paying community as made up in the main of men "whose income at the best is barely sufficient to afford them the sustenance necessary to support life, living as they do upon the barest necessaries of life." Sir Charles Elliott, Chief Commissioner of Assam, wrote in 1888, "I do not hesitate to say that half the agricultural population do not know from one year's end to another what it is to have a full meal."

AVERAGE INCOME OF THE PEOPLE.

Says the *Indian Witness*: "It is safe to assume that 100,000,000 of the population of India have an annual income of not more than $5.00 a head."

Writes an American missionary, located in southern India (1902): "I think the most trying experience I ever had was a three weeks' tour in September of last year (1901). . . . My tent was surrounded day and night, and one sentence dinned in my ears perpetually—'We are dying for lack of food.'. . . . People are living on one meal every two or three days. As one of our Christians said, 'If we can eat food once in two days we will not ask for more!' In my own missionary experience I once carefully investigated the earnings of a congregation of 300, and found that the average amounted to less than a farthing a head per day. They did not live; they eked out an existence. I have been in huts where the people were living on carrion. . Yet in all these cases there was no *recognized famine!*" In Heaven's name, if this is not recognized as famine, what is it? Think of human beings compelled to live on a farthing a day! The missionary continues: "The extreme poverty of the poorer classes of India offers conditions which are altogether extraordinary. Life is the narrowest and hardest conceivable, with no earthly prospect of any improvement; the necessities of life have been so cut down on every hand that to a Western man, even though familiar with the poverty of the West, it never ceases to be a wonder how such a delicate and complex organism as that upon which human life is physically dependent can be kept running on the scanty supply afforded. For a family of, say six persons, there is many an outfit, which including house, utensils, furniture, clothing and all, is worth less than $10.00. The average income for such a family will not exceed fifty cents per head per month, and will more frequently be found to be very little over half that. It may, therefore, be surmised that not much of this income is spent upon the cultivation of the mind, sanitation, or the appearance of the dwelling and surroundings. Even the luxury of a bit of soap, some clean water and a towel, is, on the cheapest possible scale, far beyond their means, as soap and towel would take, if regularly used, about ten per cent. of the entire income."*

* Quoted in "Condition of the People of India," by Wm. Digby, (1902) pp. 14-15.

Let us turn to official estimates of income. In 1882 Major Evelyn Baring, Finance Minister to India (now Lord Cromer), made an estimate of the average income per head of the Indian people, and placed it at about twenty-seven rupees a year. In a speech delivered March 27, 1901, Lord Curzon, the present Viceroy, estimated the average income of the agricultural portion of the Indian population (85 per cent. of the whole) to be twenty rupees per person. In his Budget speech of August 16, 1901, Lord George Hamilton, then Secretary of State for India, claimed that the average Indian income is thirty rupees. These are the most authoritative official estimates that we possess. On the other hand, Mr. Wm. Digby, C.I.E., who had long experience in India, published in 1901, the most full and exhaustive study ever given to the world of the financial and industrial condition of the Indian people, in which he furnishes evidence which seems to be overwhelming and unanswerable (certainly it has not yet been answered) to show that the average annual income of the people is not higher than seventeen and a half rupees per head.* Mr. Digby's conclusions are probably as near the truth as it is possible under present conditions to attain.

However, even if we accept the higher estimates of Major Baring, Lord Curzon and Lord George Hamilton, we have a state of things that is quite startling enough. A rupee is equal to about thirty cents in Canadian or American money. Thus we see that the average sum upon which the people of India must subsist (according to estimates of these officials, whose interest it is of course to make the sum appear the highest possible), is not above from $6.00 to $9.00, per year, or about two cents a day for each person. The average annual income of the people of England is about £40 per person, or twenty-six times that of the people of India. The average annual expenditure on intoxicating drinks in Great Britain is about £4 per person, or two and a half times as much as the people of India have to expend upon food, drink, clothing, fuel for cooking and warmth (in many parts the winters are cold) education, recreation, religion, medicine, everything necessary for a civilized existence! Is it any wonder that the Indian peasant can lay up nothing for a time of need? Is it any wonder that when his crops fail for a single season he finds nothing between himself and starvation?†

In these figures, and these quotations from men who know whereof they speak, mostly Englishmen and many of them present or past high

* "'Prosperous' British India," London, T. Fisher Unwin, pp. 46 and 661.

† In this connection we may well bear in mind that it is the extreme destitution of the people of India that is principally responsible also for the devastations of the Plague. The loss of life from this terrible scourge is very startling. It reached 272,000 in 1901, 500,000 in 1902, 800,000 in 1903, and over 1,000,000 in 1904. The plague feeds upon those multitudes of the people whose physical vitality has been reduced by long semi-starvation. So long as the present destitution of India continues, there seems small ground for hope that the plague can be overcome.

officials of the Indian Government, it is plain that we have the real cause of famines in India. That cause is not lack of rain; and it is not over-population. It is the extreme, the abject, the awful poverty of the people.

CAUSES OF THE IMPOVERISHMENT OF THE PEOPLE.

And now we come to the deepest, the crucial question of all. Why does this terrible poverty exist? Is it necessary? Is there no remedy for it? India is a land rich in resources beyond most other lands in the world. It would seem as if her people ought to live in plenty, comfort and security, with ample and more than ample provision made in her many fat years against any possible lack in her few years of comparative leanness. Why does not the fatness of her fat years prevent suffering and starvation in the lean?

Fortunately, here too an answer is not difficult to find when once we begin really to look for it. The intelligent and educated classes among the Indian people all see it clearly. Many Englishmen see it, both in India and in England. It will throw light upon our inquiry if I quote some utterances from Englishmen best acquainted with the Indian situation.

Said John Bright in 1858: "If a country be found possessing a most fertile soil, and capable of bearing every variety of production and that notwithstanding the people are in a state of extreme destitution and suffering, the chances are there is some fundamental error in the government of that country."

Much earlier still Edmund Burke declared that British friendship had brought greater ruin upon India than the hostility of invaders. Here are his strong words: "The Tartar invasion was mischievous; but it is our protection which destroys India."

Sir John Shore, who afterward became Governor-General of India, as long ago as 1787, made a careful study of the effects of foreign rule in India, and in an extended paper on the subject said: "There is reason to conclude that the benefits are more than counterbalanced by evils inseparable from the system of a remote foreign dominion."

Bishop Heber, in March, 1826, writing of his experience in India, laid great stress upon the heavy taxation, and said: "It is an effectual bar to everything like improvement; it keeps the people, even in favourable years, in a state of abject penury; and when the crop fails, in even a slight degree, it involves a necessity on the part of the government, of enormous outlays in the way of remission and distribution, which, after

all, do not prevent men, women and children dying in the streets in droves, and the roads being strewed with carcasses. . . . I have met with very few public men who will not, in confidence, own their belief that the people are over-taxed, and that the country is in a gradual state of impoverishment."*

Mr. Frederick John Shore, of the Bengal Civil Service, wrote in 1837: "The halcyon days of India are over; she has been drained of a large proportion of the wealth she once possessed, and her energies have been cramped by a sordid system of mis-rule, in which the interests of millions have been sacrificed to the benefits of the few."

Mr. Montgomery Martin, a historian of the British Colonies and Dependencies, wrote in 1838: "So constant and accumulating a drain, even on England, would soon impoverish her; how severe, then, must be the effect on India, where the wages of a labourer is from two pence to three pence a day."†

Prof. H. H. Wilson, historian of India, says of the annual drain of wealth: "Its transference to England is an abstraction of Indian capital for which no equivalent is given; it is an exhausting drain upon the country, the issue of which is replaced by no reflux; it is an extraction of the life-blood from the veins of national industry which no subsequent introduction of nourishment is furnished to restore."‡

Mr. A. J. Wilson, in an article in the *Fortnightly Review*, of March, 1884, wrote: "In one form or another we draw fully £30,000,000 a year from that unhappy country (India), and there the average wages of the natives is about £5 per annum, less rather than more in many parts. Our Indian tribute, therefore, represents the entire earnings of upwards of six millions heads of families—say of 30,000,000 of the people. It means the abstraction of more than one tenth of the entire sustenance of India every year."

Mr. Herbert Spencer gave much attention to Indian affairs, and again and again bore strong testimony against what he characterized as the "cunning despotism which uses native soldiers to maintain and extend native subjection," the "grievous salt-tax," "the pitiless taxation which wrings from the poor ryots nearly half the products of the soil," and that arrogant assumption which "tacitly assumes that Indians exist for the benefit of Anglo-Indians."

In January, 1902, Mr. Josiah Oldfield, D.C.L., said in a letter in the

* Bishop Heber's "Memoirs and Correspondence," by his widow. Vol. II., p. 413.
† History, etc., of Eastern India, Vol. II, p. 12.
‡ "History of British India," Ed. 1858, Vol. VI., p. 671.

London Daily News: "I have just returned from a study of the Indian problems on the spot. . . . I have seen brave, honest, hard-working, economical people, toiling on week after week, with only a piece of bajri or towar bread and a handful of pickles to keep it down, and a drink of buttermilk twice a day. . . . There is no famine in India at the present time; but I have visited scores of villages and have entered many a house, and have found the corn bin already empty or nearly empty. . . . Their scanty harvest has already been sold to pay the tax, and in another two months they will have nothing at all left. . . . Their wives' ornaments were sold last year, and even their copper cooking pots had to go to the market, and now they have nothing to sell. . . . Are we going to allow the present form of government to go on, which allows remediable evils to remain unremedied, which is taking taxes from people who are in a state of semi-starvation, and which is spending money so obtained on absentee landlordism?"*

Two or three years ago Mr. S. S. Thorburn, Ex-Financial Commissioner of the Punjab, a distinguished Indian administrator, declared that the present British system of government in India has resulted in reducing 70,000,000 of human beings, for whom Great Britain is responsible, to such a condition of hopeless penury that no reform can now do them any good.

Says Mr. R. C. Dutt, author of "The Economic History of India": "In India an amount equal to about one-half the net resources of the country is annually taken away from the country, and thus renders the people helplessly poor. It is a drain unexampled in any country on earth at the present day; and if England herself had to send out one-half of her annual resources to be spent in Germany or France, or Russia, there would be famines in England."

These utterances of English students of India, and of distinguished officials connected with the Indian Government, help us to see both how great is the impoverishment of the Indian people, and some of the causes which have produced it.

THE PEOPLE DEPRIVED OF THE POWER OF SELF-PROTECTION.

The causes of India's impoverishment are many. One, which in a sense is fundamental to all the rest, is the subject condition of the people. India has no self-government,—no voice whatever in making her own laws. She is ruled by aliens. This means that she has no power to guard her own interests, to shape her own industrial development

* Quoted by Mr. Wm. Digby in "The Ruining of India," 1902, p. 25.

beyond certain very narrow limits, or to protect her sources of wealth from spoliation. This is an evil situation for any nation. What country in the world would not become impoverished by a century and a half or two centuries of foreign rule and foreign exploitation such as India has been subjected to, with all power of self-protection denied her people? Not that the rule has been bad because it has been British, but because it has been *foreign*. Any other foreign rule would have been as bad—probably worse. Not that the exploitation has been bad because it has been British, but because it has been *exploitation*,—exploitation of a subject people who had no power, by a dominant people who had all power. As Macaulay said: "The heaviest of all yokes is the yoke of the stranger."

HEAVY TAXATION.

An important cause of India's impoverishment is heavy taxation. That taxes in India are heavy has sometimes been denied. But here is an easy test. Turn to England and Scotland. Scotchmen and Englishmen groan under the weight of their taxes; but the taxation of the people of India is three times as great according to their income as that of the people of England, and four times as great as that of the people of Scotland. And this means very much more than three or four times as great hardship, because the income of the Indian people is so much more meagre and inadequate to begin with.

Take a single item of taxation, that on salt. Salt is a necessity to the people, even to the very poorest. They must have it or suffer the most serious physical consequences. What is the tax which for many years has been imposed on salt? Two thousand per cent. on its value! That is to say, for every cent's worth of salt the poor Indian labourer has eaten he has had to pay the government twenty cents for permission to eat it! Of course such a tax has been well nigh prohibitory to millions of the people. They have been compelled to reduce the amount they have consumed to the very lowest minimum; and as a result serious diseases have often been entailed. Recently the tax has been slightly reduced, but it still remains so high as to be a severe hardship to the poor and a menace to their health.

The attention of the government has been called again and again to the very heavy taxation of the people, and every possible means has been tried to secure amelioration, but without result. For many years the settled policy has been, not to lessen the burden of taxation upon the peasant except under the most extraordinary circumstances, but constantly to seek opportunities for increasing it.

In justification of the present high rates of taxation, we are sometimes told that under their former rulers, the great Mogul Emperors, the people were taxed more heavily than they are now. But how does that help the present situation? Is it enough for an enlightened Christian power of the twentieth century to be as good as, or only a little better than, a cruel and tyrannical Mohammedan power of the sixteenth century? As a fact, however, it is probable that the taxes of the Mogul Emperors were not so burdensome upon the people as the present taxes are, for three reasons: First, the Mogul taxes were not collected nearly so rigidly as are the taxes of the present time. Second, the Mogul land taxes were collected from the ryots, or small farmers, in *kind*, in *produce*, whereas the present taxes are collected in *money*. But it is the requirement that the taxes must be paid in money that makes the hardship so great in an agricultural land like India. Third, the taxes of the Mogul Emperors were spent at home, in India; they were not sent away to a foreign land, as so much of the present Indian revenue is, to the steady depletion of India's resources.

A GOVERNMENT BY FOREIGNERS.

It has often been pointed out that the British Government in India is the most expensive government in the world. And of course the expense all has to be borne by the Indian people. The reason of the great expense is, the government is carried on, not by the people themselves, but by men from a distant country. These foreigners, having it in their power to fix their own salaries, naturally do not err on the side of making them too low. Having, as they say, to "exile themselves from their native land," they want plenty of pay for it. Nearly all the higher officials in India are British. To be sure the Civil Service is nominally open to Indians, but it is hedged about with so many restrictions (among others, Indian young men being required to make the long journey from India to London to take their examinations) that for the most part they are able to secure only the lowest and poorest places. The government excludes the people of India from eighty per cent. of all salaries and pensions of £100 and upwards, reserving them, as a distinguished Indian civilian says, "for English boys wishing for a wealthy career among the starved people of India."

It is not strange that the Indian service is popular with Englishmen. Those who enter it are required to spend in it only twenty-five years (indeed only twenty-one years actually in India, since four years are allowed for furloughs), and then they are permitted to return to England when little past middle age, and spend the rest of their lives there, living in ease and luxury on their rich pensions and the money which they have

been able to save from their large Indian salaries. In the Indian Civil Service there are 130,000 Indians, whose average salary is £36 a year, and 8,000 Europeans, whose average salary is £607 a year, or seventeen times that of the Indians. A Parliamentary Return, submitted in 1892, gives £13,930,554 and £3,284,163 as the sums paid respectively to the Europeans and to the Indians on appointments in India of the annual value of £100 and upwards.

These figures help us to appreciate the force of the declaration of Mr. R. N. Cust, a retired Indian civilian, living in England on Indian money: "Englishmen grow fat on accumulations made in India, while the Indian remains as lean as ever. . . . Every post of dignity and high emolument, civil and military, is held by a stranger and a foreigner."*

Is it said that the higher positions must be reserved for the English because they alone are able to fill them? No mistake could be greater. There are thousands and thousands of Indians capable of filling these positions well, far better than, in too many cases, they are now filled by the utterly inexperienced young Englishmen (often scarcely more than boys) who know nothing about the country or its people, but who, because they are Englishmen, are often given precedence over Indians of the largest experience and knowledge.

It should not be forgotten that the Indians are a civilized and gifted people—probably the most gifted in Asia—not stupid semi-barbarians as many seem to think. They have had a great history; they possess a great literature; they have given to the world two of its greatest religions. The higher caste Hindus of the north of India are related racially with ourselves; they are Aryans, belonging to the same ethnic family with the leading peoples of Europe. Lord Curzon, the present Viceroy, reminded his brother Englishmen a year or two ago that India was a highly civilized land, with arts, letters and profound philosophical systems at a time when the ancestors of the English were painted savages running wild in the woods. Should such a people be excluded not only from all part in their own government, but from nearly all positions of honour and emolument under the government? Thousands have equipped themselves with the best education that the best colleges and universities of India and Great Britain can afford. Should that education count for nothing? A few of the higher positions in different departments of the Civil Service (none in the military service) have been given them, and they have proved not only their intelligence, but their integrity and ability in all offices which they have been permitted to hold. Said Sir Thomas Munro, Gov-

* "Linguistic and Oriental Essays," Part II., chapter 7. (Trübner & Co.).

ernor of Madras: "they are better accountants than Europeans, more patient and laborious, more intimately acquainted with the state of the country and the manners and customs of the inhabitants, and are altogether more efficient men of business." Why then are they not allowed an equal chance with Europeans?

Only the blind can fail to see how great a burden upon the people of India is their present government by foreigners,—who pay themselves such enormously high salaries and pensions, and who remain in the country the shortest time possible, never identifying themselves permanently with its interests, but quitting its shores as soon as possible after their prescribed term of service expires, and carrying away their wealth to spend it in a distant land.

UNNECESSARILY HEAVY MILITARY EXPENDITURE.

Another heavy, unnecessarily heavy, burden upon the Indian people, is the large and ever growing expenditure of the government upon the army. In India the military element is strong, and has great influence with the government, and it always clamors for more and more money. Within the past twenty years, in a time of profound peace, when no new dangers threatened in any quarter, the military expenditure has nearly doubled; and we are told that still larger expenditures are ahead. I am not complaining of the support of such an army as may be necessary for safety. My complaint is—and this is the complaint of millions of the loyal Indian people—that the country is taxed to maintain an army far larger than is needed. The truth of this claim is seen in the fact that with perfect safety to India, the government was able to withdraw from Indian garrisons and camps and send to South Africa, at the time of the Boer war, 13,200 men, and to China during the Boxer rebellion, 21,300 men. (These are Lord Curzon's figures). Why should the Indian people be taxed to maintain troops that they do not require:—to make their country a rendezvous for military forces to be used for imperial purposes in distant parts of the world?

A still more serious ground for complaint is that the Indian people have had to pay vast sums for wars and military campaigns entirely outside of India, of no benefit to India, and against which they have protested, for example, in Afghanistan, Beluchistan, Burmah, the Soudan, and Egypt. The expenditures for outside wars during the nineteenth century, which Indian taxpayers were compelled to meet, reached the enormous sum of $450,000,000. Could anything be more unjust? How much of this kind of thing could any land endure without impoverishment?

Attempts have been made to justify these wars and these expenditures on the ground that they were necessary for the defence of India. No such justification is possible. In nearly every case they have been wars of pure aggression and conquest, waged for the purpose of extending the boundaries of the British Empire. The latest illustration is the recent military campaign in Tibet, disguised under the name of a "peaceful mission," but an act of aggression both in its inception and its execution, costing $5,000,000 and several thousand lives. If the Empire is going to carry on wars for the purpose of extending its territory and power, at least let it pay the expenses, and not lay them as new burdens on the back of poor India!

THE TRUE DEFENCE AGAINST RUSSIA.

Attempts have been made to justify India's large army and heavy military expenditures on the ground of danger from Russia—fear of a Russian invasion. The folly of such a fear has been shown again and again by military men themselves. There is no danger from Russia so long as India is contented and loyal. Distant Russia can no more conquer a loyal India than she can conquer distant Japan and China. Danger can arise only on the condition of India becoming discontented and ready to welcome Russia. Let us tax India, lay burdens on her, deprive her of her rights, refuse to listen to her just complaints, until we have created in her people a spirit of desperation and revolt, and then there will be a danger which all our military outlays will be powerless against. Some Englishmen see this. Said Sir Auckland Colvin: "If we enter upon a course of excessive measures of fresh taxation, Russia, without moving a man or a gun, need only abide her time." This distinguished Indian administrator saw the true and only permanently effective defence of India against Russia. That defence is to be found in an Indian government free from injustice and oppression, which guards the interests of the people, promotes their prosperity, and thus makes them contented and happy and loyal.

THE DESTRUCTION OF INDIA'S NATIVE MANUFACTURES.

Another very serious cause of the impoverishment of the Indian people is the destruction of so many native industries, through government taxation, tariff enactments and other legislation. When the British first came to India, the land was full of manufactures; it was one of the first manufacturing countries of the world. India's cotton goods, silk goods, shawls, muslins of Dacca, brocades of Ahmedabed, pottery of Scind, jewelry, metal work, lapidary work, were famed in many lands.

Now nearly all these industries are broken down, and the millions of people who used to be engaged in carrying them on, are scattered, impoverished and driven back on the land, to divide the already too scanty income of the ryot. More and more India has been forced to become a mere producer of raw material for British manufacturers, while her own native manufactures have been crushed out. Let me give the testimony of an English historian on the subject. In Mill and Wilson's "History of British India,"* we read: "In the early days of the East India Company's rule, fabrics produced by Indian weavers supplied the markets of Europe; and men now living can remember when every village in the weaving districts had its looms and millions of Indian weavers were supported by that profitable industry. How this industry was gradually strangled and destroyed, first by protective duties imposed on Indian goods in England, and then by unequal competition. . . . forms one of the saddest chapters in the history of British India." India was a great manufactory of both cotton and silk goods, which were shipped to all civilized lands. "These goods," continues the historian, "were sold at a profit in British markets at a price from fifty to sixty per cent. lower than those fabricated in England." So they must be destroyed. The British mills of Paisley and Manchester "were created by the sacrifice of Indian manufactures. Had India been independent, she would have retaliated; would have imposed preventive duties upon British goods, and would thus have preserved her own productive industry from annihilation. This act of self-defence was not permitted her: "she was at the mercy of the stranger." Such is the tragic story of the destruction of India's manufactures, told by one of England's most careful historians. India was not permitted to protect herself: "*She was at the mercy of the stranger.*"

Defenders of the policy pursued in India inform us that if old industries have declined or been broken down, the British have introduced new industries. In a measure this is true. The British have given India railways, jute-mills, coal mines, tea plantations, and many things else. These are important, but they would be more important if they were in the right hands. The trouble is, for the most part they do not belong to the people of India. Nearly all belong to the British; their profits go to the British; they are a part of the wide-spread exploitation of the land by means of which nearly all the more important sources of wealth are gathered into the hands of the ruling race.

* Vol. VII., p. 385, London, 1858.

THE DRAIN OF WEALTH FROM INDIA TO GREAT BRITAIN.

This brings me to the greatest of all the causes of the impoverishment of the Indian people. It is the steady and heavy drain of wealth that is going on, and has been going on for a century and a half, from India to England. I have already several times referred to this drain, but it should be spoken of more definitely.

Just what is it? It is India's "indirect tribute" to Great Britain. It represents the savings from salaries of officials, sent home to England; pensions of officials who have retired and are living in England; interest on English investments of many kinds made in India; profits sent home to England from business transactions in India; and the various kinds of financial returns that come back to England as the result of the many forms of industrial and financial exploitation of India carried on by Englishmen, growing out of the advantages which they possess there as the Dominant Power. Part of this drain is included in what the Indian Government calls "home charges;" but only a part, there are large amounts besides which are purely private in character. Says a British Parliamentary paper: "Great Britain, in addition to the tribute which she makes India pay her through the customs, derives benefit from the savings of the service at the three Presidencies being spent in England instead of in India; and in addition to these savings . . . . she derives benefit from the fortunes realized by the European mercantile community, which are all remitted to England."* Of course the effect on India of the draining away of her wealth to another land is the same whether done through private or public channels. Edmund Burke, referring to India, said, it "must always have been evident to considerate persons that the vast abstraction of wealth from a country, lessening its resources in proportion to the increase of its burdens," is not good, and cannot be long endured. Lord Salisbury, in 1875, spoke of India as a country "where so much of the revenue is exported without a direct equivalent." Sir George Wingate explains the effects of the drain with great clearness. Let me quote his words: "Taxes spent in the country from which they are raised are totally different in their effect from taxes raised in one country and spent in another. In the former, the taxes collected from the population are again returned to the industrial classes. . . . But the case is wholly different when the taxes are not spent in the country from which they are raised. They (such taxes) constitute an absolute loss and the extinction of the whole amount drawn from the taxed country, and might as

* Parl. Paper, 1853, (445-II.), p. 580.

well be thrown into the sea. Such is the nature of the tribute we have so long exacted from India. . . . . From this explanation some faint conception may be found of the cruel, crushing effect of the tribute upon India."*

THE AMOUNT OF THE DRAIN.

How large is this drain,—this tribute which India pays to England each year? The question is not very easy to answer, because the streams through which it flows are many, and the Indian Government seems to make efforts to keep them as far as possible out of sight. In the quotation which I have made from Mr. A. J. Wilson in the *Fortnightly Review*, he estimates the amount as £30,000,000 ($150,000,000) a year. Mr. Dadabhai Naoroji, of London, (late M.P.), agrees with these figures, and has repeatedly given to the public the financial data upon which his estimate is based. Mr. Wm. Digby places the sum at from £25,000,000 to £30,000,000, and in his great work on the subject publishes with much fullness the facts and figures which are the grounds of his conclusion.† Mr. R. C. Dutt, a very high authority, who has written the "Economic History of India" from 1757 to 1900, names £20,000,000 as a very conservative estimate.‡

Says Mr. Alfred Webb (late M.P.), an Anglo-Indian official, who has studied the subject with care: "In charges for the India Office (in London); for recruiting (in Great Britain—soldiers to serve in India); for civil and military pensions (to men now living in England, who were formerly in the Indian service); for pay and allowances on furloughs (to men on visits to England); for preparations in England for the military establishment in India; for private remittances and consignments (from India to England); for interest on the Indian debt (paid to parties in England); and for interest on railways and other works (paid to shareholders in England), there is annually drawn from India and spent in the United Kingdom a sum calculated at from £25,000,000 to £30,000,000" (between $125,000,000 and $150,000,000).**

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* "India," March 16, 1900, p. 123.

† "'Prosperous' British India," especially Chapters VI. and VII.

‡ If we consult statistical tables of India's exports and imports we find that her exports are regularly about £20,000,000 in excess of her imports. According to the official Indian Budget for 1899-1900, we find £22,024,500 ($106,818,825) set down as the sum paid by the Indian Government for "net expenditures in England charged on the revenues of the year with the exchange added." The more common figures given us in England and in statistical year books are, for that year, £16,392,486 (for the years 1903-1904, £17,619,300). The difference comes from difference of manner of estimating. One is more complete than the other, but neither covers all the wealth sent from India to England. Very large amounts are transmitted privately, in one form and another, every year, which are never mentioned in any statistical report. But even the official figures given above are enormous.

** *The British Friend*, April, 1900.

Such is the drain from India to England to-day according to the most careful and reliable estimates, made largely by men connected officially with the British or the Indian Government, or with both. If this drain were for a single decade or even a single year it would be bad enough. But India's tribute to her foreign conquerors began with the day she came into their power and has continued ever since.

First of all she was compelled to pay to the victors every penny of the cost of the long and bloody wars which resulted in her subjugation. With the first conquests, the flow of treasure to England began, and it increased as the conquests went on. India was then one of the richest countries in the world; but, all too soon she was to become one of the poorest. The great industrial prosperity of great Britain, which began about the middle of the eighteenth century, and which was unparalleled in any other European country, owed its origin to the sudden and vast influx of wealth from India. Says Mr. Brooks Adams: "Very soon after Plassey (fought in 1757) the Bengal plunder began to arrive in London, and the effect appears to have been almost instantaneous. . . . Possibly since the world began no investment has ever yielded the profit reaped from the Indian plunder."* The amount of treasure wrung from the conquered Indian peoples, and transferred from Indian hoards to English banks between Plassey and Waterloo (fifty-seven years) has been variously estimated at from £500,000,000 to £1,000,000,000.

The methods of plunder and "embezzlement" by which nearly every Briton in India enriched himself during the earlier history of the East India Company, gradually passed away. The difference between that earlier period and the present time is that India's tribute to England now is obtained "according to law;" but the amount of it is not less than in the earlier days. Indeed it actually increases. In the *Westminster Gazette*, of London, (April 24, 1900), the estimate is made that the drain from India to Great Britain during the last twenty-five years of the nineteenth century, aggregated £500,000,000 ($2,500,000,000). These figures are so enormous as to be incredible were they not undeniable. Is it any wonder that India is impoverished? Is there any country in the world that would not be impoverished, and her people be driven to starvation by such a pitiless and never ceasing financial drain?

THE CLAIM THAT INDIA IS PROSPEROUS.

Many supporters of the present condition of things in India assert that India is prosperous. In a sense this assertion is true. But whose

* "Law of Civilization and Decay," (Swann, Sonnenschein & Co.), pp. 259-264.

prosperity is it? It is the prosperity of the British; it is not the prosperity of the Indian people. The British have all power in their hands. They make the laws; they fix their own salaries; they make such offices as they see fit, and fill them; they grant franchises; they control the tariffs, the coinage and issue of money, the railways, the telegraphs, the foreign commerce, and a large part of the domestic commerce. Is it any wonder that they are prosperous? But how about those that eat the crumbs that fall from the masters' tables? No people are prosperous whose average daily income is a cent and a half per person. No people are prosperous when a man like Sir William Hunter can say of them, forty millions go through life on insufficient food.

We denounce ancient Rome for impoverishing Gaul and Egypt, and Sicily and Palestine and her other conquered provinces, by draining away their wealth to enrich herself. We denounce Spain for robbing the New World in the same way. But England is doing exactly the same thing in India, only she is doing it skilfully, adroitly, by "enlightened" modes of procedure, under business and judicial forms, and with so many professions of "governing India for her advantage, and enriching her by civilized methods" that the world has been largely blinded, and she herself is largely blinded to what is really going on. But probe down through the surface of fine words and legal forms to what lies below, and we have the same hideous business that Rome and Spain were engaged in so long, and for which in the end they paid so dear. Called by its right name what is it? It is national parasitism. It is one nation living on another. It is a stronger nation sucking the very life-blood of a weaker.

BENEFITS CONFERRED ON INDIA BY GREAT BRITAIN.

Is it said that Great Britain has done much for India, and conferred upon her substantial benefits? This is true: I would be the last to underestimate or to have others underestimate the value of whatever good to India has come from British rule. But this side of the case has been so long and loudly proclaimed to the world, that it is time something was said on the other. The rule of one nation by another is a very different thing when looked on from the side of the rulers and from the side of the ruled; just as slavery in the old days was very different when seen from the standpoint of the master and from that of the slave. It is time the world knew something of the Indian situation as it appears to the people who pay the taxes, who have had their rights of self-rule and self-protection taken from them, who do all the starving when the famines come, whose wealth has been sent away to enrich a distant land, who have felt the iron of five or six generations of exploitation by foreign conquerors

pressing down into their souls. It is time too for the world to begin to hear the testimony of those Englishmen, both in India, and at home, some of whom I have quoted above, who can see with other eyes than those of the Indian official and bureaucrat; who have hearts and consciences; who can put themselves in the place of the Indian people; who believe that justice and the Golden Rule ought to be as binding in Asia as in Europe. It would be incredible that a nation like Great Britain, ruling India so long, and sending there so many able and excellent men, should not have accomplished some good. But what about the evil? Shall that count for nothing?

The Indian Government is praised for its generosity because it appropriates certain sums of money from its treasury each year (relatively to the need very small sums) for objects of permanent public benefit. But where is the generosity? Is not every rupee in the Government's treasury Indian money? Does a penny of it come from any English source? The inquiry that should be made is, why are not vastly larger appropriations made for ends of permanent public benefit?

The Government is often pointed to as an example of remarkable benevolence because it furnishes doles to so many of the starving in times of famine. But if it has taken from the people unnecessary taxes, and thus helped to bring them to the verge of starvation, is it very great benevolence to give them back enough of their own money barely to keep the breath of life in them?

EDUCATION IN INDIA.

Much credit has been given to the Indian Government for education. It has done some good work in this direction, for which let it have full praise. But how little has it done compared with the need, or compared with what the people want, or compared with its ability, if it would only use its resources primarily for India's good! Why has so little of the people's money been spent for education? In the schools of India, of all kinds, high and low, there are some 4,418,000 scholars (if we include the native states). But what is this number in a population nearly as large as that of all Europe? How much does the Indian Government spend annually for education? The munificent sum of one penny and a fifth per head of the population! Think of it! Is it any wonder that after a century and a half of British dominance, the number of persons in India, who can read and write, is only about eleven in a hundred among males, and one in two hundred among females? With their native industries so badly broken down, the Indian people have special need for industrial, technical,

and practical education. But their rulers are giving them almost nothing of this kind. Britain's neglect of education is a dark stain upon her treatment of India.

RAILWAYS.

We are pointed to the railways of India as a striking illustration of what England is doing for her dependency. Yes, whatever lack of money there may be for education, or for sanitary improvements, or for irrigation, or for other things which the people of India so earnestly desire and pray for, the Indian Government always seems to have plenty for railways. Why? Primarily because the railways benefit the English. It is true that the Indian people use them, and derive certain advantages from them; but they also suffer from them certain very serious disadvantages. The railways have been a powerful factor in breaking up old industries, and thus have brought hardship and suffering to millions of the people. But they enrich the ruling nation, and they give her a firmer military grip upon her valuable dependency, and hence money can be found for them and for the army, whatever else suffers. What a commentary it is upon the present management of India that seven and a half times as much money is spent by the Government annually on railways as on irrigation, and six and a half times as much on the army as on irrigation; and that thirteen times as much is spent on railways as on education, and twelve times as much on the army as on education!

INDIA AND JAPAN.

It has been said that Great Britain can rule India better than India can rule herself. A sufficient answer to this claim would seem to be India's increasing famines, increasing impoverishment, and the increasing discontent of her people. But another answer also is seen in the relative condition of Britain-ruled India and self-ruled Japan. When the British came on the scene India was the leader of Asiatic civilization; she was far in advance of Japan. Time has passed. India has been ruled by a foreign power; Japan has governed herself, and shaped her own development. What has been the result? Which country now is in the advance? India or Japan?

BRITAIN AS A PEACE-MAKER IN INDIA.

We are pointed to the *Pax Britannica* as a great boon conferred upon India by Great Britain. The truth is, India has always been a more peaceful country than Europe, and the Indian people are more peaceful by nature than the English. Indeed this was the reason why they fell so easy a prey to the English. India's worst wars have been those which

she has fought in resistance to her numerous invaders, Asiatic and European. She had some wars of a serious character in connection with the breaking up of the Mogul Empire, which was itself a foreign domination; but of all her modern wars none are to be compared for magnitude or for destruction of life and property with the Napoleonic wars and several others among European nations. If there was need for a strong foreign power to come into India to compel her to keep the peace, there was and still is much more need for a strong foreign power to come into Europe to compel her to keep the peace. The bloodiest of all India's wars for many centuries have been those waged by the British for her conquest. Peace conferred as the result of such wars is a questionable boon to be conferred upon any land. How would Europe like it? How did Britain herself like it when Rome conferred it upon her under Julius Cæsar and his successors? It has been estimated that the total number of deaths from war in the whole world during the 107 years from 1793 to 1900 was about 5,000,000,—an awful record surely! But, this number is only one-half that of the deaths caused by famine in India in a single decade of that 107 years, according to the estimate of *The Lancet*. Verily there may be a peace that is worse than war. Some of these facts should be borne in mind when we undertake to estimate the value of the *Pax Britannica* to India.

MUST THE PEOPLE OF INDIA BE KEPT "HEWERS OF WOOD AND DRAWERS OF WATER" FOR FOREIGN MASTERS FOR EVER? IS ENGLAND HELPING THEM IN THE DIRECTION OF ANYTHING BETTER?

We are told that Great Britain is training the Indian people, and preparing them for self-rule by and by. I wish this were true. The best Englishmen ever since India came under English control have urged that this ought to be the aim, kept steadily in view. But it has not been and it is not now. Whatever slight tendencies there may have been in this direction under Lord Ripon, or any earlier rulers, of late have been entirely laid aside. For twenty years, and more, but especially under Lord Curzon, the spirit of the Indian Government has been distinctly reactionary, toward less of sympathy with Indian aspiration, greater severity of treatment of the people, restricting still more their few liberties, and pushing still further away the day of their hope for any degree of self-rule. Mr. Moorfield Storey, of Boston, asked Sir Andrew Clarke, the distinguished administrator of the Straits Settlements, and a high authority on British Colonial Government: "Have these centuries of British rule

brought the Indian people any nearer to self-government than they were when British rule began?" He answered, "Not a bit." What he said is true, and it is Britain's shame and crime. It is also a blunder, which if persisted in will bring disaster; for even Indian patience will not endure forever.

THE ROOT OF THE TROUBLE.

What does all this that I am saying about India mean with regard to Great Britain? Does it mean that Britain rules India worse than other European nations would do? On the contrary, as I have already indicated, I do not believe that any other nation, European or American, would rule India so well. The fault does not lie with the want of humanity of the British people. I am myself an Englishman. I am keenly sensitive to anything which seems to throw disparagement upon the honour or character of my countrymen. The men whose strong words I have quoted in support of nearly every position taken in this paper are eminent and loyal Englishmen. I believe in the British nation. I believe that the people who abolished slavery in their colonies when their eyes were opened to see its wrong, need only to be made aware of the real condition of things in India to set about a change. The fault lies primarily with the *system* of *holding* and *governing foreign peoples without their consent.* Abraham Lincoln said, there is no man good enough to govern another man. It is equally true that there is no nation good enough to govern another nation. Said Macaulay: "Of all forms of tyranny I believe the worst is that of a nation over a nation." Imagine the case our own. Suppose Canada had been ruled for a hundred and fifty years by a foreign and distant power, like Germany or Russia. Suppose that power responsible to nobody but itself, and possessing absolute and sole control in everything,—in making and administering our laws, in shaping our tariffs, in building and managing our railways, telegraphs, telephones, and steamboat lines, in issuing franchises, in owning and managing our mines, forests and lands, in everything connected with our economic and industrial as well as political life,—what condition would Canada be in to-day? Would our people be rich or would they be miserably poor? If there were prosperity, whose would it be, ours or our our foreign ruler's?

THE REMEDY.

What needs to be done to lift India out of her present impoverishment, and hence out of her always impending liability to famines? The answer has been given many times over by some of the ablest students of the

Indian situation. What has been said in this paper suggests it. The main matters may be summarized in a few sentences:

Cut off all military expenditures outside of India; and if the British Government wants to carry on foreign wars let them be paid for, as they ought, out of the imperial treasury.

Inaugurate a policy of trust of the Indian people, in place of the present policy of distrust.

Reduce the expenditure on the army by at least one-half.

Check that extravagance of railway building which has swallowed up such vast sums of money, and carried the railway system of India far beyond the needs of the country.

Push forward irrigation with greater vigour, and thus increase the productivity of the land.

Bring the vast area of waste land into use by drainage and otherwise, and thus make it available for the service of the people and for revenue.

Fill fewer offices with high priced European officials, and more with equally competent native men, whose expenses will be less and who know the real needs of the country far better than foreigners can.

Reduce taxation, and extend throughout India the plan of "permanent settlements," which has worked so well in Bengal.

Establish a wide-spread system of agricultural banks or government credits, so that the millions of small farmers who must pay their taxes in money before their crops can be sold, may not be driven into the hands of merciless money lenders.

Take measures to build up again the ruined manufacturing industries of the country.

See that no tariff laws injurious to Indian interests are enacted either in India or Great Britain.

Spend at least five times as much as is now done, on education; and especially push forward education in its practical and industrial forms.

Inaugurate wide-spread and comprehensive methods for improving agriculture.

Let the Government lay aside some of its imperialistic arrogance, cease spurning Indian public opinion, and begin listening to the voice of

the people as expressed in their public press, their conventions, and especially their very able and widely representative Indian National Congress.

Above all, let the Government give to the people a share, and a steadily increasing share, in their own local, municipal, provincial, and national governments, and thus put into their hand some real power of self-protection, which is the only safety for any people.

In a word, let it be the ambition of Great Britain, not to keep India under her feet, but to lift her up to England's side, as she has done Canada and Australia. Then, but not before, will prosperity begin to take the place of impoverishment and famine, and a new day will dawn for the Indian people.

ON THE ABSORPTION OF FAT IN THE INTESTINE.

By G. E. Wilson, M.B., Tor.,
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(*Read 6th May*, 1905).

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I.—Introduction.

One of the most keenly discussed questions in physiology for the last forty years has been the manner in which the absorption of fat takes place in the intestine and the question is still, after so long a period of debate, as far from settlement as it was a generation ago. The basis of the discussion has been shifted somewhat recently, but the point of contention still is whether the fat passes into the epithelial cells in part as very fine particles in the form of a so-called emulsion and in part also in a dissolved condition, or only in a dissolved form as the products of hydrolysis, glycerine, fatty acids and soaps.* The former view had the support of Brücke, Kölliker, Donders, Eimer, von Basch, von Thanhofer, Grünhagen, Heidenhain and others while it was opposed by Pflüger, Cash, Ludwig, and Rindfleisch, and the number of its critics have increased in recent years with the result that the balance of opinion is inclined in favour of the other view.

What has told in favour of the alternative view is the advance in our knowledge of the action of digestive juices on the fats, which goes to show that fats are broken up into simpler compounds by the steapsin

* A complete account of the literature of this subject may be found in Oppel, Lehrbuch der Vergleichenden mikroskopischen Anatomie der Wirbelthiere, Zweiter Theil, Schlund und Darm, 1897; Kischensky, zur Frage über die Fettresorption im Darmrohr, Ziegler's Beiträge, Vol. 32, p. 197, 1902; Croner, Die neueren Ergebnisse der Frage von der Fettresorption, Biochemisches Centralbl, Vol. 3, p. 93, 1904.

of the pancreatic juice and to a certain extent also by the gastric juice, these simpler products, owing to their solubility in the chyle, diffusing as readily into the epithelium as do the peptones and the hydrolyzed carbohydrates. From this point of view the digestion and absorption of fat are not different fundamentally from the digestion and absorption of proteids or of carbohydrates, and therefore, the occurrence of a special process in the case of fat, such as does not obtain in the case of proteids and carbohydrates, was questioned and generally rejected.

In spite of the preponderance of observation and opinion against the view that fat is in part absorbed as fine particles in the form of an emulsion, there have not been wanting in recent years supporters of that view and amongst them may be counted Rosenthal,* Connstein,† Beneke,‡ Munk¶ and Rosenberg.** Included also is Kischensky,†† who has brought forward evidence which, in the opinion of the writer of this paper, meets the objection that no one has demonstrated the passage of fat particles through the striated border of the epithelial cells.

This observer employed in his technique a new micro-chemical reagent, scarlet red (Scharlach Rot), an azo colouring compound, introduced by Michaelis,‡‡ which is insoluble in water, acids, alkalies, slightly soluble in alcohol and readily soluble in chloroform and in fatty oils. Owing to its affinity for fats and fats alone, and in consequence to the intense red colour which it gives to the finest particles, this reagent is a very much more sensitive one than osmic acid which was previously regarded as the final test for fat in tissues.

Kischensky, by the use of this reagent, found very minute fat particles in the striated border of the villi in kittens, and that these particles, after passing through the border and reaching the underlying protoplasm, fuse to form larger, readily demonstrable droplets. He does not, however, regard this as the only manner in which fat enters the epithelial cells for he expressly states that the greater part of the fat is absorbed in the soluble form and that only a small portion goes through the striated border in the form of very fine particles. He further holds that in full grown cats the fat particles are transferred to the parenchyma by the cytoplasm of the

* Lehrbuch der allgemeine Physiologie, 1901.

† Ueber die Resorption und Assimilation du Fette, Die Med. Woche, No. 15, 1900.

‡ Die Fettresorption bei natürliche und künstliche Fettembolie und verwandten Zuständen, Beiträge zur Path. Anat. und zur allg. Path., Vol. 22, p. 343, 1897.

¶Zur Frage der Fettresorption, Centralbl. für Physiologie, Vol. 14, pp. 129 and 153.

** Zur Physiologie der Fettverdauung, Pflüger's Arch., Vol. 85, p. 152.

†† Zur Frage uber die Fettresorption im Darmrohr und den Transport des Fettes in andere Organe. Beiträge z. path Anat. und z. allg. Path., Vol. 32, p. 196, 1902.

‡‡Die indifferenten Farbstoffe als Fettfarbstoffe.—Deutsche Med. Wochenschrifft, 1901, p. 183. Also: Ueber Fettsfarbstoffe, Virchow's Arch., Vol. 164, p. 263, 1901.

cells, but in kittens the fat may pass not only through the cytoplasm, but also through the intercellular spaces to parenchyma.

The writer had, before Kischensky's paper came to his knowledge, begun the study of the absorption of fat and had, through Michaelis' observations, been led to employ scarlet red as a micro-chemical reagent for fat. With this and other means he carried out the work, and when it was completed, arrived at results which are, in many respects corroborative of those obtained by Kischensky, but were obtained from a larger number of vertebrate forms. These results are now published in the hope that they will serve in some degree to advance the solution of the question of the mode of absorption of fats.

II.—Methods of Study.

During the first five months guinea pigs were almost exclusively used. Sometimes they were kept from all food for as many as four days before they were employed, while others were not so treated. They were fed on egg yolk diluted sufficiently with tap water to allow the mixture being drawn up into a pipette used for feeding, and fifteen to twenty cubic centimetres of this were given to each three times a day. At the outset of the investigation many of the animals were fed on diluted yolk to which one cubic centimetre of dialysed iron was added on each occasion. Others again were given only pure olive oil. Some were fed only once, and killed from three to six hours afterwards, others were fed one, two or three days, while a few were continued on this diet alone until death ensued. The rest of the animals employed were invariably killed with chloroform, the abdomen was at once opened, the duodenum exposed, and pieces about a centimetre and a half long, and one half a centimetre broad taken from different portions, were placed in Flemmings Fluid for about twelve hours. The composition of this fluid was:—

0. 1 per cent. chromic acid, 15 parts.

2. per cent. osmic acid, 4 parts.

One part glacial acetic acid was added to nineteen parts of the above when about to be used. The specimens were then washed in running water for half an hour, placed in fifty per cent. alcohol, after about twelve hours in seventy per cent. for twenty-four hours, then in ninety-five per cent. for another twenty-four hours, and finally into absolute alcohol for periods varying from twelve to seventy-two hours. When it was considered necessary the absolute alcohol was changed and fresh added.

Some of the specimens were then passed through chloroform into paraffin while others were infiltrated with celloidin before being imbedded in paraffin. Owing, however, to the presence of chromic acid in the fixing agent the proteids are so coagulated that not enough is left unchanged in the sections to cause the latter to adhere, so that in most cases a small amount of collodion and oil of cloves had to be employed for attaching the section to the slide. In a few instances the sections were made adherent with albumen and glycerine.

The preparations were treated after the iron-alum hæmatoxylin method, followed by eosin staining. Numerous other stains were used but this method gave by far the best results so that it was the one chiefly used. With this stain the nuclei stand out as blue black, the cytoplasm takes the eosin, while the fat is black or, if not very abundant and seen with the diaphragm of the microscope well open, a brownish tinge is evident.

With the view of investigating more closely the striated border I experimented with other fat stains, and finally obtained what I required in scarlet red (Scharlach Rot). This stain is insoluble in water, but soluble in seventy to eighty per cent. alcohol. It is also soluble in soap solution, but insoluble in glycerine or chloral hydrate, five per cent In using it one must be careful to get a solution of proper concentration, else the results are very unsatisfactory. It requires to be shaken from time to time with seventy, or even eighty per cent. alcohol for three or four days and then filtered. Before using it should be tested on a little olive oil smeared on a slide, when, if good, it will give a deep red reaction to the globules in about one minute.

In my first experiments I used guinea pigs fed for about three days upon olive oil. They were then killed with chloroform about three hours after the last feeding, the abdomen opened, a piece of the duodenum was put into ten per cent. formalin for about forty-eight hours, then frozen with carbon dioxide spray, and sections made about six-seven microns thick. These were put into the scarlet red solution for about forty-five seconds, then transferred to tap water for a few seconds and mounted in glycerine, the edges of the cover slip being later smeared with melted paraffin.

III.—Structure of a Villus.

Before dealing with the subject proper I wish to refer briefly to the structure of certain cellular elements of a normal villus of the duodenum of a guinea-pig.

The epithelial cells covering the villus are columnar, their length being approximately three to four times their width at the outer edge. They lie upon a basement membrane in which there are no nuclei. The majority of histologists describe this membrane as containing nuclei, but I have never been able to satisfy myself that they are present. It is true that in many cases nuclei appear to be present, but on very careful examination one will invariably find that such a nucleus belongs to an adjacent capillary. It is an easy matter to demonstrate blood capillaries lying adjacent to the basement membrane, and in specimens where the red corpuscles do not stand out prominently it is not difficult to fall into error.

When the epithelial cells are at rest, no demonstrable space exists between adjacent cells, their edges being closely approximated from upper to lower end. During their active stage, however, as I shall point out further on, their lower ends become separated. This separation I believe to be due to the contraction of the lower end of the cell so that the length of the cell is increased. The reasons for this view I will give later on when discussing the extrusion of the fat from the epithelial cells.

The striated border is particularly interesting inasmuch as no one, heretofore, except Kischensky, has been able to demonstrate fat within it. In the literature of the subject it is usually represented as having a distinct and clearly defined outline both above and below. It is a simple matter to demonstrate the sharply defined lower margin of this striated border; in fact one can readily see it in teased out preparations, but the distal edge is not equally well defined. Heidenhain* has indeed called attention to the changeable character of the outer edge and Kischensky and others have noted the same fact. I have examined a great many specimens of epithelium from various animals, and as a result, find that the striae are unequal at their distal ends. Further, I have on many occasions seen striae terminating as rodets distally. And it is perhaps what one might regard as probable, for in the higher invertebrates the epithelial cells of the intestine are ciliated, and in the larvae of frogs, also the epithelium is ciliated, while that of the adult frog is only striated. Again as I shall show later on these striae are able to pick up particulate

*Pflüger's Arch. Vol. 43, Supplement, p. 91.

substance, thus adding further weight to the contention that the striae have free ends.

Within the parenchyma of the villus is to be found a variable amount of smooth muscle fibre together with connective tissue strands. These latter branch in various directions between the basement membranes of the epithelial layer and the wall of the lacteal, leaving anastomosing spaces of irregular size and shape between. Within these spaces and also in the connective tissue are to be seen four main types of cells,—the ordinary polymorphonuclear leucocyte, the lymphocyte, the "mastzell," which, however, does not stain with the ordinary dyes, but can be easily demonstrated with methylene blue and, lastly, cells, which I have termed large lymphoid cells, varying in size from about ten to twenty microns in diameter, and from a spherical to a more or less elliptical outline. Their nuclei are, as a rule, eccentrically placed, and are usually vesicular. The outline of these cells is generally clearly defined, and the protoplasm takes the eosin stain, appearing as finely granulated. As far at least as the guinea pig is concerned, I have never seen these large lymphoid cells within or between the epithelium covering the villus nor in the lacteal, in this respect differing from the other leucocytes. They are, however, actually phagocytic as will be shown later on. They are precisely similar to the cells described by Macallum as containing iron when salts of that element are being absorbed from the intestinal cavity.*

The number of leucocytes in the villus is subject to great variation. The majority, however, during fat absorption, at least, are of the large lymphoid character and are especially numerous at the tip of the villus, a point of considerable importance when one remembers that most of the fat enters at that place.

It is noteworthy too that in the guinea pig very few leucocytes of any description are found either within or between the epithelium covering the villus, and this is true whether active fat absorption is going on or not, a fact of very great moment in relation to one of the older theories of fat absorption. In the same animal, too, one very seldom sees a leucocyte in the lacteal vessel.

The occurrence of lymphatics, with well defined walls within the parenchyma of the villus is still in doubt. I have on several occasions tried to inject such, using soluble Prussian Blue dissolved in gelatin, but failed to demonstrate them. The difficulties, however, are great owing to the valve at the base of the villus. I am convinced, nevertheless, that

*On the Absorption of Iron in the Animal Body, Journal of Physiology, Vol. 16, p. 268 1893.

they are not present. That there are lymph spaces, however, I feel certain, and there is quite conclusive evidence to show that the spaces between the epithelial cells of at least their basal thirds, are in direct communication with these intraparenchymatous lymph spaces, because one can frequently demonstrate streams of fat going direct from these spaces in the epithelium to the wall of the lacteal. (Figs 2, 5, and 8).

IV.—FAT IN THE EPITHELIUM.

That the fat enters the villus directly through the epithelial cells can no longer be questioned. When a guinea pig is fed on fat containing food for a day or two and killed about four or five hours after the last feeding, and the preparations stained as above outlined, the picture is conclusive. Fat droplets of various sizes are seen throughout the cells. Although there is no uniformity regarding the size of these drops the largest are usually seen towards the distal (free) end, (Figs. 1 and 14). Above the level of the nuclei the fat is often intercellular, (Fig. 7). At the level of the nuclei and below them it may be intracellular (Figs. 4 and 9), or intercellular (Fig. 5), but below the nuclei most of the fat is between the cells. I do not wish to convey the idea that the nuclear zone is a hard and fast line of demarcation, but there is a difference in the distribution of the fat in the cell above and below it. I am aware that Heidenhain claims that the fat only goes into these intercellular spaces when in excess. Von Basch holds that it is present only in a sort of backwash. The former explains its presence between the cells by the contraction due to the fixing agent, whereby the fat is squeezed out of the parenchyma into the intercellular spaces. This one cannot accept, for preparations from frogs fed with olive oil for a day or two and killed about three hours after the last feeding are decisive. The intestines of these fixed with 10 per cent. formalin for twenty-four to forty-eight hours, sectioned on the freezing microtome and the sections stained in scarlet red and mounted in glycerine show these intercellular spaces to be filled with fat. If, however, before they were treated with the fat stain they were placed in ether for about half a minute, these spaces which before were red are now light, the fat having dissolved out. If one saw fat in these spaces only in shrunken sections Heidenhain's explanation would appear the more probable one, but it is such a constant feature in well preserved sections that one must endeavour to account for it in some other manner. I believe therefore, that the fat is to a large extent excreted by the cell activity into these intercellular spaces. Watney believes that the fat is taken up wholly between the cells. Against this may be placed

the fact that in properly prepared sections the most striking thing in the field is the great amount of fat inside the epithelial cells.

Bruyne claims that there is connective tissue between the epithelial cells, containing lymphatics so that leucocytes can penetrate between the cells and pick up fat from the intestinal contents. He is of the opinion that all the fat lying between the cells has been deposited there by these leucocytes. So constantly have I found the fat between the cells that I cannot accept this explanation. If leucocytes are instrumental in placing the fat there one would expect to see them in abundance between the epithelium, but in the guinea pig at least their occurrence there is a rarity.

Not uncommonly one sees more or less irregular circular spaces just beneath the striated border which are clear and free. They are found after treatment with 10 per cent. formalin, saturated bichloride of mercury, or absolute alcohol, and even with Flemming Fluid if the osmic acid is not of the usual strength. They are due to fat globules having dissolved out leaving vacuoles behind. In some cases one can see these spaces containing just a small amount of fat, in others the spaces are filled while the next cell has a vacuole, (Fig. 8). Adjacent cells do not necessarily take up an equal amount of fat. Very frequently one sees several adjacent cells loaded with fat while others near them are free from it.

The nuclei of the epithelial cells never contain fat. It is true that a section will at times apparently show fat in the nucleus, but it is due to the way in which the section is cut, the fat in the cytoplasm then appearing under or above the nucleus.

Concerning the presence of fat in the striated border special reference is made below.

V.—FAT IN THE PARENCHYMA.

When a guinea pig is fed fat in excess the adenoid tissue of the villus is black with it. (Figs. 2 and 12). It lies in the spaces between the leucocytes and the fat streams communicate freely in all directions. In some instances, especially when the fat is not abundant, minute drops of fat are visible and these frequently present the appearance of a row of minute beads, the series being directed generally toward the lacteal. (Fig. 8). In others the droplets have coalesced into large masses of fat, which take the shape of the spaces through which the fat is passing, (Fig. 5). It is frequently possible to trace these fat streams proceeding directly from the basal end of the epithelial cells, (Fig. 8), but much more com-

monly do we find them connected with the interepithelial spaces, (Figs. 5, 6 and especially Fig. 8). Again one can demonstrate fat within the lower third of the epithelial cells and reaching almost to the basement membrane and yet not going directly towards the lacteal, but, instead, being excreted into the interepithelial space and pressed into the parenchyma as a fine stream, (Fig. 5). In the same drawing one can see the fat within the epithelium streaming towards the interepithelial space. For these reasons I feel justified in stating that most of the fat is excreted into these interepithelial spaces which apparently are in direct communication with the large, fat-containing space of the parenchyma. Within the fat streams, especially at the tip of the villi, numerous leucocytes, more or less laden with fat, are to be seen. (Fig. 1). At the sides of the lacteal, however, where the leucocytes are much less numerous one can frequently trace fat streams from the basement membrane to the lacteal without the intervention of leucocytes, a point which adds considerable weight to the contention that the leucocytes play a minor role in the transference of the fat through the adenoid tissue of the villus. Often too the only leucocyte intervening is a polymorphonuclear one which, so far as I can make out, never takes up fat, (Fig. 2).

I have already stated that I regard these fat-containing spaces as connected with the central lacteal on the one hand, and with the interepithelial spaces on the other. In any event one can, with the greatest ease, demonstrate fat streams going direct from these interepithelial spaces through the parenchyma to the wall of the lacteal, (Fig. 8).

VI.—Transfer of Fat Through the Parenchyma.

There have been various views put forward as to how the fat is carried through the adenoid tissue. Von Basch* believes that the connective tissue strands are channeled and that the fat proceeds through these openings. As Heidenhain† has pointed out, such coarse strands of connective tissue are not to be seen unless produced by shrinking and bad technique so that Von Basch's theory has no basis of fact to support it. The contention of Zawarykin‡ that the leucocytes send out pseudopodia and take the fat from the epithelial cells and later discharge it against the lacteal wall cannot be substantiated. I have carefully examined many hundreds of sections and have seen nothing which could be so interpreted. The question now arises: what part do the leucocytes take in the transfer of

*Sitzungsber. der Wiener Akad., Math. Nat. Cl, Vol. 62, p. 1, 1870.
†*Op. cit.*
‡Pflüger's Archiv, Vol. 31, p. 231, 1883.

the parenchymatous fat? The answer to this question involves a determination of the part played by the leucocytes in the absorption of fat from the intestinal contents.

If the leucocytes are wholly or to a large extent responsible for the transfer of fat one would expect to see a vast increase in their number when a guinea pig has been fed pure olive oil. Such an increase is not found. When a guinea pig, ordinarily fed, is killed, the sections show about the same number of leucocytes, at least their increase is not at all proportionate if they are so necessary for the transference. It is true that the majority of the leucocytes present are of the large lymphoid variety, but the same is true when iron is being absorbed. Then when the adenoid tissue is laden with fat one would expect to see every leucocyte in the central portions of the parenchyma, at least, more or less filled with fat, while those leucocytes near the basement membrane, and the lacteal wall should show many variations according as they were laden or uncharged with fat. On the contrary no such variation can be demonstrated, and the centrally placed cells contain no more fat than those near the chyle vessel or the basement membrane, (Fig. 12). Moreover, when so much fat is to be transferred one would expect to see these leucocytes discharging it near or against the lacteal wall, but I have never been able to demonstrate such a condition. Furthermore, if the leucocytes are so active in carrying fat one would expect them to be laden with their burden in some direct ratio to the abundance of fatty material. No such ratio exists. In some sections these cells are surrounded with fat, yet the lymphoid cells contain none (Fig. 8). Finally fat streams can be traced from the basement membrane to the wall of the lacteal with no leucocytes intervening (Fig. 11). As already remarked there are four kinds of leucocytes in the villus, but one only is concerned in this, namely the epithelioid cell, for in the guinea pig fat does not occur in the lymphocyte or the polymorphonuclear cells (Figs. 2).

In the demonstration of the presence of fat one must not rely wholly on the result given with osmic acid, for as Heidenhain has well said: "Everything that stains black with osmic acid is not fat." In preparation from guinea pigs fed on the ordinary diet, fixed with Flemming Fluid, and stained with iron alum and eosin, dark granules are found in these large lymphoid cells, which have the appearance of fat and for some time I considered them as such. Later I noticed that in similar specimens fixed with absolute alcohol, and stained with hæmalum and eosin, these granules were present and had the same dark or black appearance. Evidently then such granules could not have been fat since the alcohol agent would dissolve all the fat out of the sections. These granules were evidently particles

of inorganic salts, probably iron, as Macallum has conclusively shown that these cells pick up that element. One can, however, demonstrate that they also contain fat. If preparations from animals fed with fat made with Flemmings Fluid be placed in ether for twenty-four to thirty-six hours, the granules, which before appeared deep black, become colourless, having slowly dissolved in the fluid. Further, if the preparation is made with ten per cent. formalin for twenty-four to forty-eight hours, and the preparations sectioned with freezing microtome and stained with scarlet red, for forty-five seconds the fat granules appear bright red. If, however, before staining they are placed in ether for twenty seconds the red granules disappear, this showing that the cells do take up fat.

As already pointed out it was Zawarykin who first brought forward the view that leucocytes were the sole means by which fat was taken up from the intestinal contents. He claimed that after picking up the fat they returned to the chyle vessels. Schäfer,* while admitting that fat droplets are present in the epithelial cells when the amount of fat in the chyme is relatively large, holds that the leucocytes are under ordinary conditions the only structures capable of taking fat from the lumen of the bowel. He says too that "no fat particles are, as a rule, found between the epithelium and the central lacteal, save such as are embedded in lymphoid corpuscles." In the guinea pig at least, and, according to Heidenhain, in puppies also, it is a rare thing to find a leucocyte of any description either within or between the epithelium. As remarked, the large lymphoid cell is the only leucocyte which picks up fat, and I have never observed such a cell either within or between the epithelium, nor have I ever seen such a cell in the central lacteal. I have on several occasions seen a polymorphonuclear leucocyte in the epithelium with fat almost surrounding it, yet containing none itself (Fig. 6). More frequently one is able to see lymphocytes within the epithelium, but always free from fat (Fig. 8). Leucocytes are present in numbers in the epithelium in young kittens, but whether they take up fat I cannot say, since I have not studied their action in this respect, but even if they do contain fat, their number is altogether inadequate to accomplish very much, a fact which tells against the view that they transfer fat through the parenchyma to the lacteal. Schäfer found that in spring frogs, which had been fed fat the epithelial cells showed considerable fat, while November frogs showed very little fat absorption, and then none was present in the epithelium, the whole being taken up by the leucocytes. He concludes from these experiments that under ordinary circumstances the leucocytes take up all the fat, while the epithelial cells act as storehouses when the fat is in

* Pflüger's Arch. Vol. 37, p. 395, and Inter. Monatschr. für Anat. und Hist. Vol. 2, 1885, p. 6.

excessive amount. The presence of fat within the cells of a spring frog may be explained in an altogether different manner. If one kills such a frog, fixes a portion of the intestine in 10 per cent. formalin for twenty-four to forty-eight hours, then places it in 5 per cent. chloral hydrate over night, and afterwards in scarlet red solution en masse for another eight to twelve hours, washing in water for a few seconds and teasing the material in glycerine furnishes a preparation which is conclusive. The whole epithelial cell is more or less filled with fat droplets like those found in the epithelium of a fat-fed guinea pig. One never, however, sees the fat in the nucleus or in the striated border in such an instance. The same is true of a starving Necturus (Fig. 17). Moreover the presence of fat droplets during the starving period is quite general as the cytoplasm of the liver cells is more or less filled with them while their nuclei give no evidence of their presence. Fat is likewise abundant in the epithe ium of the renal tubules.

From this it may be concluded that the fat which Schäfer found in the intestinal epithelium of the spring frog was, in great part, that which is normally present under such conditions. I have not had an opportunity of making observations on November frogs, but feel certain that if such were fed olive oil there would be no difficulty whatever in demonstrating fat in the epithelium. Schäfer used lard in his investigation, which on account of its comparatively high melting point is unsuited to cold blooded animals. As I shall show further on, when winter frogs are fed olive oil for several days it is possible to demonstrate minute fat drops in the striated border (Fig. 16).

VII.—Passage of Fat Into the Lacteal.

Heidenhain offers no explanation as to how the fat goes through the lacteal wall, but says that the fat does not attain a finely divided condition until it gets to the central chyle vessel. This is supported by my own observations. That the fat does not necessarily remain as very minute droplets is equally certain (Figs. 2 and 10) for one can frequently see large globules forming in the lacteal from the minute fat droplets as they have penetrated the wall. Fig. 8 illustrates the manner in which the fat penetrates the lacteal wall. The representation is from the side of a villus and one can see minute fat droplets on either side of the wall and in some instances delicate streams of fat going through. In many cases these minute droplets after entering coalesce into larger fat droplets or spherules. It may then be concluded that the fat penetrates the lacteal wall as very minute droplets of particles through numerous stomata in its

surface, these latter being especially numerous at the tip. As to the forces at work causing the fat to go towards the lacteal one can only offer conjectures as to their character. Weymouth Reid* has shown that the epithelial cells of the intestine will absorb fluids when the osmotic pressure is negative and the hydraulic pressure less upon the lumen side so that in this case the vital activity of the cells must play the most important, if not the whole part. Certainly osmotic pressure cannot have anything to do with the transfer of fat through the lacteal since it depends for its results upon the number of dissolved molecules which in this instance is nil. The epithelial cells, by their contractions, can remove the fat from within them into channels which communicate with the lacteal; the contraction of the muscles about the chyle vessel which is supplied with a valve at its base empties the lacteal and the resulting dilation causes a relatively lower pressure so that the fat is forced to go in the direction of least resistance, probably by the stimulus received from the epithelial contraction. It is generally conceded that the proteid material normally goes by way of the blood vessels, but when fed along with excess of fat it frequently enters the chyle vessel with the fat. Fig. 11 shows that physical condition cannot be overlooked in considering the causes of fat transference.

Bruch† claimed to have demonstrated that the capillaries took up fat. He described certain vessels as half filled with fat, the other half showing the normal blood reaction. Heidenhain has criticized Bruch's work and concludes that his technique was very faulty in that the whole section showed up more or less black owing to the fixing agent not having been washed out before placing in alcohol. I have never been able at any time to satisfy myself that any fat ever entered the blood capillaries, probably because, as Heidenhain suggests, the fat in the parenchyma is not in a sufficiently divided condition to enter them. Fat, undoubtedly, in other parts of the body, leaves the capillaries for the tissues, but it must be as very minute particles indeed, and if it can leave the capillary its passage in the opposite direction should not be an impossibility, but from experiments upon the percentages of fat in the portal vessels as compared with such vessels as the carotids and femorals the probability of fat entering the capillaries of the villi is negative.

As to the part supposed by some to be played by leucocytes as agents in transferring fat to the lacteal it may be stated that in the guinea pig, evidence of such an activity, except as a rare feature, cannot be found, and in fact the presence of leucocytes within the lacteal is a rare occur-

* Phil. Trans. Roy. Soc., Vol. 192B, 1900, p. 211.

† Zeit. für wiss. Zool., Vol. 4, 1853, p. 288.

rence, one having to examine many specimens before seeing an example, such as is represented in Fig. 11. The leucocyte, which is of the polymorphonuclear variety is surrounded by fat, which forms a fine meshwork, and yet contains none itself. It is perfectly formed and shows no signs whatever of disintegration. In all the preparations from the intestine of the guinea pig I have not seen half a dozen leucocytes in the chyle vessel, nor have I seen a leucocyte penetrating the wall, facts which should tell against this view. I have, moreover, never seen large lymphoid leucocytes in the lacteal,and these are the cells which, undoubtedly, pick up fat. Then too the fewness of leucocytes relative to the amount of fat to be transferred must always cast grave doubt as to the efficiency of their action in this respect. Finally, as I have already pointed out, one can frequently trace the fat as minute streams going through the parenchyma into the central vessel, and this without the intervention of leucocytes of any description. (Figs. 8 and 10).

VIII.—FAT IN THE STRIATED BORDER.

And now I come to the discussion of the most interesting part of my investigation. With the exception of Kischensky, all observers are agreed that fat has not been found in the striated border of the epithelium. From an histological standpoint, this fact has been used as a proof that fat enters the cells in some soluble form, for example, as a soap, and is later reconverted into a neutral fat through some action of the epithelium, all observers, further, regarding the fat present in the epithelium as in a neutral condition. As to the fat in the intestinal cavity a great deal of attention has been given to determine whether it is present as a soap or an emulsion, but into a discussion of this question I do not propose to enter, and it suffices to say that there is abundant experimental evidence to show that both are present. In fact, to have a permanent emulsion, one must have present an alkali and some free fatty acid or, in other words, a soap, and as Heidenhain has pointed out, it is a common occurrence to see fat droplets of various sizes lying in the lumen. Indeed, it was the presence of such minute droplets in immediate contact with the striated border, together with the view I had taken regarding the structure of the striae as enunciated in the first part of this paper, that led me to think the fat was taken up in some particulate form and not alone in solution.

In this connection, too, it is of interest to note that von Thanhofer* described a to and fro movement of the striae in the duodenum of winter frogs whose nerve roots had been severed. He claimed to have seen red

* Pflüger's Arch., Vol. 8, p. 406.

blood corpuscles and desquamated epithelium carried along by this movement and even saw fat droplets lashed into the interior of the epithelial cells. These phenomena he watched for three quarters of an hour. He could not, however, confirm these results upon spring and summer frogs, but did so once more on winter frogs. Fortunatow*, likewise, on two occasions, claims to have seen a motion like that of cilia in the striae. One asks why the same should not be observed in spring and summer frogs and, with Heidenhain, what the cutting of the nerve roots has to do with it, yet I think the view is not by any means so fantastical as later investigators suppose. Schäfer rejects it on the ground that small particles of carmine are not picked up by the epithelium. The physical properties of such particles are very different from those of very minute fat droplets and consequently one should not expect to find the same result in both cases. The occurrence of fat particles in the striated border as Kischensky's and my own observations show can only he explained as a result of the physical activity on the part of the striated border.

The most striking evidence regarding the occurrence of fat particles in the striated border is to be found in preparations treated with scarlet red, as described under Methods of Study.

When such sections are examined with an oil-immersion lens the appearance found is like that represented in Fig. 13. Large and small drops are seen within the cells while very minute, but nevertheless, quite distinct globules are seen in the striated border. Their distribution is not uniform. In some parts of the specimen no such globules are present, in others they are few, while other portions again show numerous beadlets, such variations depending, doubtless, upon the different periods of activity on the part of the cells. Often the globules are irregularly scattered throughout the border, but one can frequently see rows of beadlets running parallel to the striæ and occasionally a line of fat running the whole length of the same and having the appearance of an elongated fat droplet. Having satisfied myself that fat droplets could be demonstrated in the striated border of guinea pigs I made observations, with the aid of scarlet red, on the intestinal epithelium of frogs, cats, rabbits, dogs and Necturi (lake lizards). The frogs and lizards were in the starving condition, and the material obtained from them was placed in five per cent. chloral hydrate solution over night and teased the next morning. There is considerable variation in the striæ in all these animals, that of the rabbit being the coarsest, and in consequence best suited for demonstrating the border fat. To the first rabbit I gave 20 c.c. olive

* Pflüger's Arch., Vol. 14, p. 288.

oil without previously depriving it of food and killed it about twenty hours later. A piece of the duodenum was put into five per cent. chloral hydrate over night, then placed in the scarlet red solution for about twelve hours, removed therefrom to water for a few seconds, then teased in glycerine and mounted, and the edge of the slip being subsequently smeared with paraffin. The result was quite remarkable, (Fig. 18). In some instances the droplets were irregularly scattered throughout the border, in others they were arranged in beadlets running parallel with the striæ, in others again a string of beadlets is seen running transversely to the plane of the bodies, and at the very tips of the striæ, as though the beadlets were just entering the cell, while in still others the same elongated form of the fat droplets, as described in the guinea pig, is evident. The same technique was carried out with the dog, kitten, frog and Necturus and in each instance I was able to demonstrate fat particles in the striated border (Figs. 13, 18 and 19).

The question naturally arises: Why cannot these fat particles be demonstrated with osmic acid? That it fails in paraffin sections I believe can be accounted for by the slight solvent action of the alcohols used. While it is true that alcohol is not an active solvent for fat since you can put fat-fed specimens which have been fixed in formalin and cut with the carbon dioxide freezing method into seventy per cent. alcohol for an hour, then into ninety-five per cent. for fifteen minutes, all without any appreciable difference in the fat reaction when afterwards stained with scarlet red, yet when long continued it might readily affect that which is most accessible. It must be borne in mind, also, that osmic acid is not as delicate, or as sensitive a stain, for fat as scarlet red.

During the last few days of my investigation I directed my attention to the demonstration of fat droplets in the border by means of osmic acid. A rabbit was fed 20 c.c. olive oil, without being previously starved, and killed three and a half hours later. Pieces of the duodenum were put into five per cent. chloral hydrate over night and then into one per cent. aqueous osmic acid solution and small portions teased out from time to time in glycerine. The osmic acid penetrates very slowly under such circumstances so that not until about the fourth day do you get any marked reaction. Fig. 21 shows the appearance of the cells after four days in the osmic solution. Here too one can see fat beadlets in the striated border, and when compared with Fig. 19 the similarity is striking.

From the above considerations it is evident that fat can be and is absorbed in some particulate form. By means of scarlet red it is not

possible to differentiate a neutral fat from one of the fatty acids since it gives just as distinct a reaction with oleic and stearic acids as with neutral fats. Consequently one cannot say positively whether the droplets are fatty acids or neutral fat, although in all probability the latter. If, however, they are fatty acids, these are absorbed in particulate form and not in solution. The conclusion arrived at, therefore, from the study of the above results is that fat is taken up in particulate form by the striated border, either as neutral fat, or fatty acid,—in short as an emulsion.

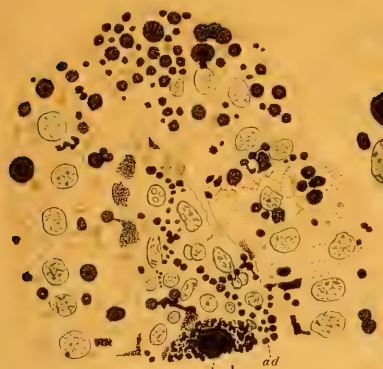
Both J. Munk* and Will† have shown that the organism, probably the epithelial cells, can furnish the glycerine radicle necessary for the synthesis of neutral fat from fatty acids so that it is immaterial as to the ultimate result whether the fat is taken up in a neutral form or as a fatty acid.

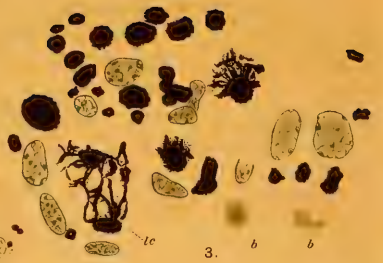
Hofbauer‡ performed certain experiments to show that fat was taken up as an emulsion. Before feeding, the fat was stained with Alkanna Roth or Lackroth A. These are insoluble in water, but soluble in alcohol. On examination he found the fat in the villi stained. Pflüger, in criticizing Hofbauer's work points out that the stains used are soluble in bile, glycerin and soap so that the stain might readily be absorbed and colour the fat afterwards. Hence one cannot draw any positive conclusions from Hofbauer's researches. I repeated his experiments, using scarlet red, which has one advantage over Hofbauer's stains in that it is insoluble in glycerine. It is, however, soluble in soap solution. The fat in the villi was found to be coloured red. Nevertheless, when taken in conjunction with the demonstration of fat in the border it is a fact in support of the emulsion theory of fat absorption.

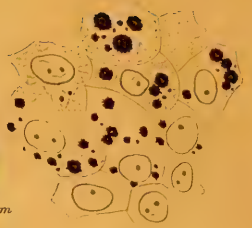
Henriques and Hansen¶ conclude from their experiments that all fat is absorbed as soap. They took equal parts paraffin and fat with a little fatty acid and added an aqueous solution of sodium carbonate. There results an emulsion in which the droplets contain an equal quantity of fat and paraffin intimately mixed. On feeding this they found that most of the fat was absorbed while the paraffin was in the excrement. Upon superficial consideration this seems to be a very strong objection to the emulsion theory. But what reason have they for supposing that their made up emulsion remains intact until it reaches the duodenum? Milk is an emulsion, but without being acted upon by the intestinal fluids

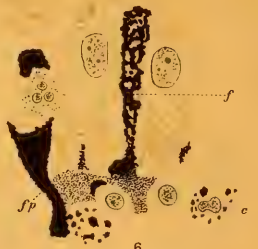
* Virchow's Arch., Vol. 80, p. 20 and Vol. 95, p. 431.
† Pflüger's Arch., Vol. 20, 1879, p. 255.
‡ Pflüger's Arch., Vol. 81, p. 263, Vol. 84, p. 619 and Zeit. f. Klin. Med., Vol. 47, p. 477.
¶ Centralbl. f. Physiol., 1900, p. 313.

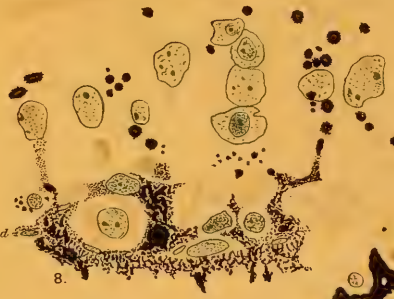
would not be absorbed because the fat globules are not nearly minute enough. Without the action of the intestine upon their artificial emulsion neither would the fat be absorbed for the same reason. The very fact that they conclude it is absorbed as soap admits of disintegration of their emulsion so that their experiments are altogether negative, neither supporting nor favouring the emulsion theory.

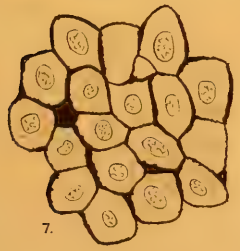


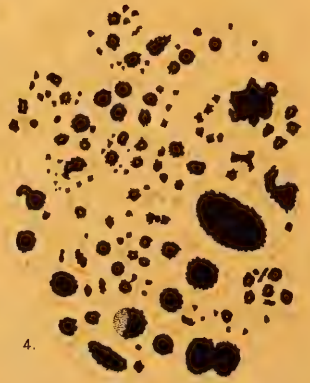


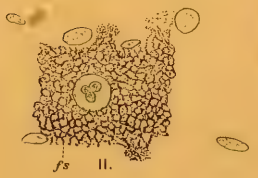




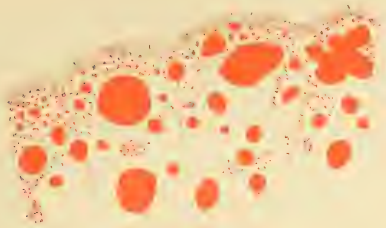








E. Wilson, Cambridge.



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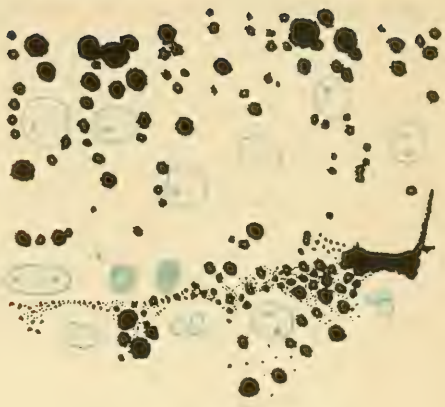

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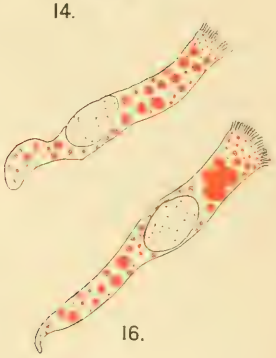

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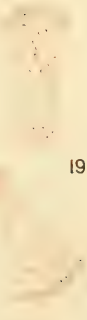

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E. Wilson, Cambridge

EXPLANATION OF PLATES.

In the various Figures *ad*, signifies adenoid tissue; *b*, blood capillary; *c*, a polymorphonuclear leucocyte; *f* and *im*, columns and masses of fat between epithelial cells; *fd*, fat in lumen of lacteal; *fl*, fine streams of fat traversing wall of lacteal; *fs*, network of fine lines of fat in wall of lacteal; *ec*, large lymphoid cells.

Figures 1—12 and 14.—From villi of guinea-pigs fed with yolk and dialysed iron. Flemming's Fluid, Hæmatoxylin and Eosin.

Figures 3 and 8 are tangential sections of the epithelial cells of the villi.

Figure 13.—From villus of guinea-pig fed with yolk. Formalin ten per cent., four and a half days, Scarlet Red. Showing beadlets of fat in the striated border.

Figure 15.—From villus of guinea-pig fed with yolk, showing contents of central lacteal with some fat droplets.

Figure 16.—Intestinal epithelial cells of frog fed with olive oil, isolated, showing fat particles in striated border. Scarlet Red.

Figure 17.—Isolated epithelial cells of intestine of starving Necturus, showing droplets of fat in cytoplasm, but none in striated border. Formalin, Scarlet Red.

Figure 18.—Isolated epithelial cells of the intestine of a Necturus fed with olive oil, showing the distribution of fat in the striated border and in the cytoplasm. Formalin, Scarlet Red.

Figure 19. Epithelium, isolated, from duodenal villi of rabbit fed on olive oil, showing beadlets of fat in the striated border and in the cytoplasm. Formalin, Scarlet Red.

Figure 20.—Isolated epithelial cells from the intestinal villi of a dog fed on olive oil, showing fat in the striated border as villus in the cytoplasm. Chloral hydrate, Scarlet Red.

Figure 21.—Isolated epithelial cells of the intestinal villi of a rabbit fed on olive oil and killed three and a half hours afterward. Osmic acid for twenty-four hours.

TREES AND THEIR INDIVIDUALITY AND RELATION TO OUR DAILY LIFE.

By J. McPherson Ross, Esq.

(*Read 10th February*, 1906.)

I must apologize to you for the incomplete character of this paper, as some features which should have been ready in connection with it, I have failed to prepare, but crave your indulgence as this one is but introductory and seasonable to this time, and the after part will be continuous and appropriate if not exhaustive. If a youth and early manhood spent in the then largest tree nursery existing in Canada—in daily contact and close observation with all the operations carried out as they would occur during the changing seasons of the year, combined with a natural love to know things about trees, give me any right to address you on this subject, then I may modestly claim that right to-night. You

Maple Planted in Allan Gardens by King Edward.

all know how much of late the subject of trees and all matters relating to Forestry have engrossed the public—conventions have been held and valuable papers read by experts on the best means of restoring these

conditions of forest wealth, and other economical questions relating to our daily life and the welfare of the country at large—conditions resulting from the policy which must be changed if we are to enjoy our existence at all.

We have no doubt that when the governments of this continent are fully seized of the great value of preserving our forests, some practical policy will be adopted to preserve what is left and to restore partially what has been denuded or destroyed. I may be pardoned if I state in passing that as far back as the seventies, I frequently wrote articles then calling attention to the suicidal policy of the people in destroying the woods—pointing out as far as I could the criminal folly almost of such practice that we were killing the goose that laid the golden egg by such gross wastefulness—and that we should have then a department that would make it its business to educate the public to preserve and restore by replanting for the future the woods it had taken centuries of the past to produce. I am sorry to say my warnings were not heeded and my voice along with many others was literally as of those crying in the wilderness. Nor can you wonder very much at the indifference displayed—one had only to go to the Queen's Wharf and see acres of timber being made in great rafts to be towed down the lake—every train steaming down from Barrie, Lefroy, and Gravenhurst, bearing its continuous burden of huge squared logs or cordwood—"Such abundance! such opulence of forest wealth! what? ever be scarce, ever be dear, what nonsense!" Now we are striving to repair our extravagance by replanting, and we must work hard and work quickly for we are not yet experienced foresters. Cutting down woods, thinning and replanting and how to produce forests on a business basis come by experience. We know how to destroy, do we know how to restore? The only answer to this is to replant and here we can appreciate the lines of the poet, Joaquin Miller, when he says:

"God gave us Mother Earth" full dressed
In robes of green of ample fold;
We tore the green robes off her breast,
We sold our Mother's robes for gold,
We sold her garments fair, and she
Lies shamed and bleeding at our feet.
In penitence we plant a tree—
We plant a tree and call it meet."

And here we may pay tribute to a class of men who in many cases are regarded with scorn and open displeasure by some, while others are just as grateful to them as possibly they should be for benefits received. I mean the agents who act for the nurserymen with the public.

In arguing the question whether it was good or bad policy then to patronize them, we are face to face with this fact, that thousands of trees annually would never have been planted were it not for the persuasive eloquence and persistent energy of the much abused agents. By whatever means they took to sell the trees, they have induced thousands to plant them who would not have done so, and many an orchard now whitens the hillside with their fragrant bloom in spring, or tints the autumn landscape with the crimson and gold of their tempting fruits; many a garden yields its abundant supply of juicy strawberries or grateful and satisfying currants and gooseberry; many a vine covered arbour, or trellised wall covered with leaves and fruit of the luscious grape. Many a bleak spot or unlovely farm home is draped and graced in charming and attractive beauty by climbing vines or perfumed rose, or sheltered and protected from stormy wintry blasts with the comforting windbreak of cedar or spruce, that owe

Second Growth White Pine.

their entire and absolute existence to the eloquence of the agent, relentless and persuasive, scrupulous or unscrupulous as he may have been; to him is due many a bouquet of fragrant flowers that delight the senses with their beauties of colour and perfume. Then long may he continue in his activity, doing good as it were by stealth. But my subject is not tree agents or policies of forestry, but those distinctive qualities that belong to individual trees that meet our eyes in their various situations as we see them in our immediate neighbourhood of street and park.

To a lover of trees they are always beautiful and perhaps we are more apt to appreciate them in the summer than the winter, but even now

there are many beauties to be seen which cannot be observed when the trees are in full foliage. Gazing up at the rough or smooth barked trunks, we notice the spreading of the branches and those spaces between through which the sky silhouettes them for us. We can trace their various form and difference of growth. We notice the sturdy rugged branches of the stalwart oak or the closely placed branches of our favourite maple; we notice the white barked birch dividing into brown branches further up, finishing in string-like twigs with their pendant dried up seed bunches trembling at the tips. We can look into their very anatomy as it were and study their individuality. We follow with our eyes the long waving grey-barked branch of the beech to its furthest extremity, and speculate on the causes that make one tree rough-barked and the next smooth. Then the colour we notice in trees; we can run down the whole gamut from the paper white birch to the silvery beech and past the yellowish green of poplar or ash to the golden or crimson willow, to the yellow or black birch, to the bronzy green of the pine or the sombre blackish green of the hemlock. And then when they are crowned with a fall of snow how beautiful they look, 'tis those expressions of nature we can drink in as it were and cannot describe in all their grace. *At this* season we notice the provision nature makes in the character of the twigs and branches for the foliage they support in summer.

The large pointed buds on the sturdy branches of the chestnut are well calculated to bear the broad palmated luxuriant foliage, while the slender lace-like drooping lines of the birch are suited for the small long-stemmed leaves that flutter and waver in every passing zephyr. The stubby twigs of the irregular butternut or the blunt odd-shaped twigs of the Kentucky coffee-tree or the walnut, the hickory or down to humble sumach, the character of the buds and the sturdy branches indicate that they bear large foliage or drooping bracts of pinnated leaves. This applies to all deciduous trees—characteristics which stand out more clearly in the winter.

The opposite qualities of lightness, gracefulness in foliage and branches are readily seen in the birch, aspen, willow, elm and others.

At this time we can notice more distinctly the effect of too close planting, how dwarfed or deformed on one side is that noble oak for want of room; how cramped and disfigured is yonder maple from the close proximity of a chestnut!

The individuality of trees in enhanced or retarded by their situation or association. For large spaces near public institutions of stately architecture, the most suitable tree is the oak and next the elm. The tree adds grace to the building and the building adds dignity to the tree.

Speaking locally, I always feel sorry for St. James' Cathedral and sorry for the poor worn out chestnuts that surround it. They have crowded and starved each other and should be removed. They are a decaying eyesore and hide and mar the beauty of the building by the density of growth of dying branches and general decrepitude. A careful observation of the trees in Toronto reveals the fact that there are very few good specimens of any tree. There are some elms, but very few of the other kinds—all are more or less affected by crowding. A few trees in our neighbourhood have had greatness thrust upon them. Foremost of these is the scarlet maple planted by His Majesty King Edward, then Prince of Wales, in the Allan Gardens. This tree is quite shapely and promises after forty-five years of growth to become a beautiful tree.

Alongside is a Norway maple, planted by Prince Arthur, September 7, 1869. The placard says October, but that is wrong as I helped to dig the tree in the nursery and brought it up in full leaf to the Gardens, held the tree while the prince threw in a spadeful of soil and assisted in finishing the task. The people surrounded us and soon stripped every leaf off it as souvenirs and saved us the trouble.

Golden Willow

Across from that is an English oak, characteristic of that variety. It was planted by Hon. G. W. Allan, on Shakespeare's birthday. I think the trees that live longest in the memories of the people are those associated with their youth, such as those grown in close proximity to schools or

that stand out in the grounds. Scarred and hacked they may be, climbed upon and ruthlessly treated, but their image remains longer in association than any other; and I deem it a beautiful custom, the planting of such a tree on some event in connection with history, or guest, or teacher or scholar, as every year adds interest to its history. It becomes a thing of life around which many associations gather and some, nay many, of the tenderest nature.

Trees are divided by sylviculturists into two classes, light-loving trees and those preferring shade. Of the former the most prominent are oaks,

English Oak.

birches, aspens and of the latter are beeches, maples, hemlocks, etc. Between these two types constant warfare is going on and though no sound is heard in the forest as booming of cannon or dropping of shells, still a persistent warfare is raging in which the shade-loving trees are finally the victors. Silently, but relentlessly they pursue their even steady growth. The beech and hemlock thrive in the shade and finally drive out the others. Nature has provided always some expeditious method of propagating all species, and none in a more prolific manner than elms and maples. In cities the variety of elm known as Wych elm is voted a nuisance. Our native white elm is not so prolific and is therefore most suited for street and park planting.

As they ripen their seed in June it is gathered by the growers when ripe and sown immediately when it grows and reaches a foot high the same

season. This is also true of the maples; but the hard maple and Norway maple ripen in the fall. I find I have said a good deal about trees in general, but very little of their individuality. A learned professor states in the papers that he thinks plants have all the senses but that of hearing. I am glad they have not that of speech, for if they were endowed with that quality we should hear plenty of complaints about our treatment of them, *but* one thing we do know, we are all growing more observant and more appreciative of nature and her works and to me nothing is grander or more beautiful than a perfectly developed tree in all its foliaged beauty. To think of that wondrous, silent life, existing above and below, those skilled chemists working continuously, but relentlessly selecting and absorbing those various ingredients to produce wood and fibre, bark and leaf and flower, even to the very tint and colour of the leaf and flower, and that last added grace, perfume, spring and summer, autumn and winter,

Typical Native Pine.

in cold and heat, in light and dark, a never failing charm to the young and old, a type of eternity!

We are fortunate in living in a latitude which is so congenial in its climate as to allow the growth of a large variety of the most useful trees, not only in those that are indigenous to the soil, but also many others that are really valuable for the many purposes we require them for, and while it would be a fascinating subject to pursue to note how the various trees have their uses in an economic sense it would prove too lengthy a

subject to follow, but just say we hardly appreciate them enough for the pleasure and comfort they afford us in the building of our homes with their timber, in the heat we derive from fuel in winter or cooking our meals, in the fruits they afford us for sustenance and refreshment, for the sheltering shade from the heats of summer, and the modifying of the winter winds by shelter belts of evergreens.

How barren would be our fields and streets without trees, in fact we could not exist and life would be simply intolerable. The individuality of a tree commences with the seed and the character of its growth is determined by the buds on its branches and the direction the growth of the branches excepting such accidents as may be affected by winds or pruning or its peculiar situation in growing. In some cases from the position of the buds on the stem, the growth is upright and in others the growth is almost at right angles.

These differences or traits determine the after-head of the tree whether it will be pyramidal—tapering inwards at the extremities as the Lombardy poplars or diverging outwards as the fan-shaped American elm or spreading or curving downwards as the Norway spruce. Orchardists must study carefully these habits in their fruit trees so that when pruning they will direct the growth in such a manner as will make them shapely and allow proper spaces to admit air and sunlight to ripen and colour the fruit. For instance the pruning required for a Northern spy apple would be different to that required for a Rhode Island greening and so on all through the whole catalogue of fruits.

We stated that the position of the buds on the branch is responsible for the after form of the tree. Thus the horse chestnut has its buds opposite to each other while on the elm the buds are alternate. To the lover of trees all are interesting and have their appointed place, but what affects us most as citizens are the trees most suitable for street planting. The horse chestnut, though common on our streets, is far too dense in its habits for streets—it obscures the view in day time and obstructs the electric light at night time. Its place is in the parks, where given suitable space it makes in time a beautiful tree. The American elm, our native tree, is the best for that purpose, growing up loftily with a straight trunk it permits vistas underneath of houses and street and the overhead foliage not being too dense permits sunlight to filter through its leaves and allows grass to grow underneath. Its appearance in our farm fields is always graceful and lends a charm wherever it occurs to pastoral scenes. The individuality of the maple tree is too well known to need any particular description, but suffice to say that it is always beautiful in every season, in bud, in leaf, in spring, in fall tis a thing of beauty and a joy forever. The numerous varieties of this lovely tree though different from each other

have each their special charm. The hard maples for the value of their wood, sugar and the sturdy shapely growth. The soft maples for the gracefulness of their growth and the pleasing and lovely tints that glorify the autumn season—all make the maple family like what Shakespeare says of Cleopatra, "Age cannot wither them nor custom stale their infinite variety."

The hickory is a lovely tree and of a picturesque habit in growth with strong foliage and shaggy grey bark—though occurring frequently in our woods, should appear in our parks more frequently than we see them.

Our two most common oaks are the red and white. The red being the most common as the wood not being so valuable as the white is allowed to grow more commonly. The bark is dark grey and close while its branches have that robust look denoting strength and sturdiness. The

Scarlet Horse Chestnut.

foliage is very ornamental and is in marked contrast by its acute dentation to the rounded lobes of the white oak leaves. The bark of the white oak is deeply serrated or reticulated, and light grey in colour. Both are light loving trees and thrive in poor dry soils. Their foliage presents most pleasing tints when changing in the autumn of olive, purple, crimson and scarlet and from their habit of retaining their leaves during winter, enliven many a dreary winter landscape by their browned foliage.

No more noble tree is grown than the beech, but its spreading ample

habits make it more suitable for the parks than contracted space of streets. For ornamental purposes the purple beech should be in every collection. Quite a fine specimen over fifty years old stands in Moss Park and when in full foliage no stained glass windows ever glowed with such crimson effulgence as does this tree when it stands between you and the sinking sun on a summer evening. 'Tis a blaze of crimson glory when the light filters through its wine coloured leaves. For such glimpses of exquisite colour it is worth going miles to enjoy and seasons to wait for. It takes a generation to present such an effect as the beech is slow in growth. They delight in good soil and thrive in the shade, particularly when young,—a peculiarity that causes them to succeed and dominate other trees in after years.

The ash trees require more than a passing notice—make good street trees and are invaluable for their timber. The trunks or bark are pleasing to note in their regular reticulation.

The mountain ash is a lovely tree for inside planting and in small places and in conjunction with white birch and evergreens, forms a pleasing picture when covered with its red berries. We hope it will always be planted freely as its berries afford welcome food to our winter birds. 'Tis a favourite tree in Scotland and often quoted by poets as the bonnie rowan tree.

Turning to soft wooded trees we must note the poplar—none of a more marked individuality than the Lombardy poplar. An occasional tree towering over and amongst groups of other trees makes quite an artistic effect and adds accent to many a pleasing scene. All the poplar family have long stemmed leaves and are easily put in motion by the slightest breath of air. In Scotland there is a popular legend respecting the "Aspen."

"Far off in the Highland wilds 'tis said,
But truth now laughs at fancy lore,
That off this tree the Cross was made
That erst the Lord of Glory bore;
And of that deed its leaves confess
E'er since a troubled consciousness.

Another poplar is the silver poplar, whose foliage is pleasing when blown by the wind and is easy of cultivation.

Mention may also be made of the tulip tree, the basswood, and the birch. Of evergreens, the white pine, the Norway spruce, the hemlock and the cedar have a particular value in winter.

I would urge every one to keep planting as something we can do, for—

We cannot measure the need of even the tiniest flower,
Nor check the flow of the golden sands that run through the single hour;
But the morning dew must fall, and the sun and the summer rain
Must do their part and perform it all over and over again.
Over and over again the brook through the meadow flows,
And over and over again the ponderous millwheel goes,
Once doing will not suffice,
Though doing will not be in vain.

MINIATURE STEAM ENGINES.

By T. H. Robinson.

(*Read 21st April*, 1906).

To those who are mechanically inclined the subject of model engines offers something of interest, yet I feel it would be presumptuous on my part to come before this learned society and undertake to tell them anything *new* about the steam engine, as doubtless many of you know much more about this subject than I do.

About a month ago your president, Dr. Kennedy, saw the little engines at my shop and invited me to exhibit them before the Canadian Institute.

An artist had just finished what he considered the finest picture he had ever painted. He invited a noted critic to come and view it.

Brass Engine. Height, 1 inch; bore, $\frac{1}{8}$ inch; stroke, $\frac{1}{4}$ inch; weight, $4\frac{1}{4}$ dwts.

The expert gazed at it long and earnestly. Finally the artist said, "What do you think I ought to get for it?"

"Oh, about six months," was the reply.

As you are the critic to-night I feel a little uneasy lest you decide I am entitled to a longer term.

Whenever we speak of an engine, we associate the word with power, and the many uses to which steam has been put by means of the engine leads to the belief that the steam engine is the most useful of man's many inventions.

By a horse power, we mean that power which is sufficient to raise 33,000 pounds one foot in one minute at the earth's surface against the force of gravity.

To a watchmaker that seems quite a lift, yet in this age of giant engine construction, both steam and electric, it no longer surprises us to read of engines capable of exerting thousands of horse power.

This evening we go to the other extreme, and consider the construction of a steam engine so small, that its power would seem to be better designated by the name of "flea-power" than "horse power."

I am not an engineer but a watchmaker, and these two engines are the only ones I have ever made; and if you think after you have seen them that they are small enough, then perhaps, I won't have to make another.

My first engine, (which we will call the large one), is one inch in height, made of brass, polished and laquered. It is an upright, with oscillating cylinder and stands easily on a five cent coin, bore of cylinder is 1/8 inch; stroke, 1/4 inch; and it weighs 4 1/4 dwts., about the weight of a wedding ring.

This engine was designed for a show window attraction and answered the purpose well as it was probably the smallest ever shown in Toronto.

When running it makes a hum similar to that made by a bee. When I began this engine I thought it would be small enough, but compared with every day watch-work, it seemed when finished to be very large. I decided to make a smaller one, something more worthy of a watchmaker's skill. About this time I was looking over some old numbers of *The Keystone*, (a jeweler's trade fournal), and came across an account of two small engines made by two watchmakers, from which it seemed that small engine making appeared to be a watchmaker's disease, of which I was just beginning to feel the first symptoms.

Like other diseases it must run its course. It's dangerous; but there is *one* chance of a neat recovery—that is, if you can make *the smallest engine*. Be thankful you have not this disease, for the size is going down.

Entomologists tell us:

"Big bugs have little bugs upon their backs to bite 'em;

"And little ones have lesser ones; and so on *ad infinitum*."

This may be true in Bugology, but there can be no *ad infinitum* in mechanics.

There must be some limit to the working size of an engine. It may be we have reached that limit in the tiny engine I will show to-night.

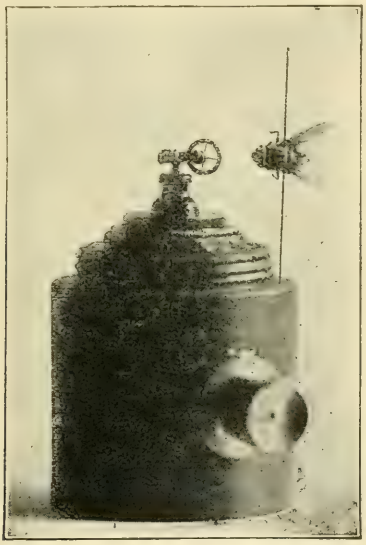
I do not show it as the *smallest* I can make because I have only tried

this thing twice, and you will notice a big drop in the relative sizes of the two engines when you compare them.

I believe I could make a smaller one if I had to, but if I recover on this one so much the better.

"Tiny Tim," as I have named this smallest of all engines, is made of gold and steel, and is so small that a common house-fly seems large by comparison. It fits easily into the smallest 22 short empty cartridge balance wheel and stand. It weighs four grains Troy complete, that is about the weight of a common match. It takes 120 such engines to weigh one ounce, 1,920 to weigh one pound, and 3,840,000 engines equal one ton.

The engine bed and stand are of gold. The shaft runs in hardened and ground steel bearings inserted in the gold bed.



"Tiny Tim," the smallest engine ever built. Photo actual size, the fly being shown for comparison. A protecting covering, not shown, can be screwed down on to the ebony base.

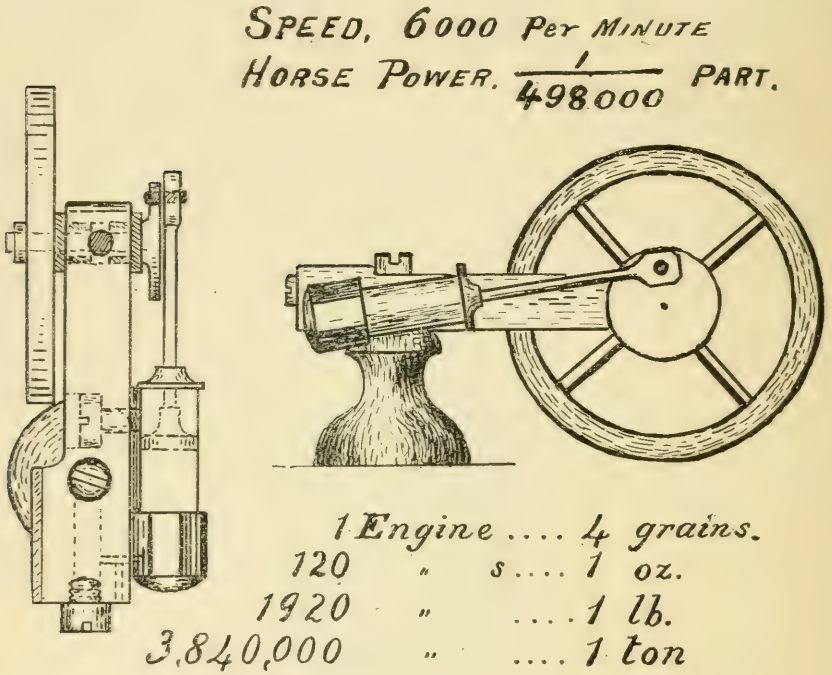
These bearings are counter bored from the inside to form a self-oiling bearing. The fly wheel has a steel centre and arms, with a gold rim; and this part, the complete wheel, weighs one grain.

The cylinder is of steel with octagonal base highly polished. The stroke is 1-32 of an inch; bore, 3-100 of an inch. Seventeen pieces are used in the construction of this engine.

The feed is through the gold base which is hollow. The speed of this engine is 6,000 revolutions per minute. When running 100 per second, no motion is visible to the eye, but it makes a note like the noise of a mosquito caused by the vibrating piston-rod.

The horse power is 1-498000 of one horse power. I am indebted to Dr. C. A. Chant, of the Department of Physics in Toronto University, for a careful estimate of speed and horse power.

He estimated the speed by means of tuning forks of known vibration.



Pen sketch showing details of "Tiny Tim" the Smallest Engine.

To look at a small object without a magnifying glass is a poor way to see it. You miss the detail of its construction, so I have had prepared a few lantern slides, which will enable us to see the action, and compare the size of the engines with well known objects and with each other.

We will use compressed air as the most convenient for operating the engines, and here it may be noted, that the stream of air necessary to make the *large* engine hum, may be sustained on the eyeball without winking or causing any inconvenience.

After the slides are shown, you are invited to come forward and

examine as best you can the smallest engine on earth, and see it demonstrated by high speed that the principles which actuate the steam engine as a pressure machine still hold good even in this small sized and speedy machine.

Sometimes I am asked by the practical ones, "Why did you make them?" "What use can they be put to?" Well, it has been a pleasure to make them, and they have given pleasure to hundreds who have visited the shop and who can appreciate small and accurate work. Their pricipal use, I fancy, is in the building line—reputation building—and so far they have done good work.

NOTE—Both engines were then exhibited running at high speed, and were examined by aid of magnifying glasses.

IS BELIEF IN A GLACIAL PERIOD JUSTIFIED?

By Henry De Q. Sewell, Assoc. M. Inst., C.E.,

(*Read 21st April*, 1906.)

Is the belief in a Glacial Epoch justified? is a question that may well be asked by thinking geologists, sixty-six years after it was first promulgated by Agassiz, who in 1840 wrote that, "If the analogy of the facts he had observed in Scotland, Ireland and the North of England, with those of Switzerland be correct, it must be admitted that not only glaciers once existed in the British Isles, but that large sheets of ice covered all the surface." He also urged "that glaciers did not descend from the mountain summits into the plains, but that they were the remaining portions of sheets of ice, which at one time covered the flat country." "It is evident," he says, "that if they descended from high mountains and extended into the plains, the largest moraines ought to be the most distant, and to be formed of the most rounded masses, whereas the actual condition of the detrital accumulations is the reverse, the distant materials being widely spread and true moraines being found only in the valleys connected with great chains of lofty mountains." He, however, admitted that he had never seen till until he visited Scotland and Mr. J. Geikie says, "We cannot fail to remark that although scratched and polished stones occur not unfrequently in the frontal moraines of Alpine glaciers, these moraines do not at all resemble till or boulder clay. The moraine consists for the most part of a confused heap of rough angular stones and blocks and loose sand and débris, scratched stones are decidedly in a minority, indeed a close search will often fail to find them. Clearly then till is not of the nature of a terminal moraine." And again he says, "We look in vain among the glaciers of the Alps for such a deposit as till; the scratched stones we may occasionally find, but where is the clay? Thus at the very outset the theory which Agassiz based on a supposed analogy between the British Isles and Switzerland, is shown never to have existed, that true moraines are only to be found in valleys connected with lofty mountains, also that moraines are not of the nature of till. So we may well ask with Prof. Young that since fifty to sixty per cent. of till consists of impalpable mud, why was it not washed away by the waters constantly present beneath moving ice? Again Agassiz postulates that not only the Baltic Sea, but the German Ocean, also was bridged across by ice, on which many boulders were transported from Scandinavia and that this

immense ice sheet extended from the Arctic Ocean. J. Geikie, however, admits that the direction of glaciation in the extreme north of Scandinavia, the peninsula of Kola Finland radiated outwards from the high grounds of Norway and Sweden flowing north and north-east into the Arctic Ocean and White Sea. Again if we turn to this continent we have the evidence of Dr. Dawson, who says of the Arctic Coast of America that erratics moved northwards. Dr. Bessels, says re Smith's Sound, latitude 81°.30′ "the trend of boulders is from south to north," and Dr. Bell says the same of Hudson's Bay. Hence it is conclusive that if we postulate the existence of an ice sheet, it did not and could not have extended from the Arctic Ocean, but from some point further south, otherwise its northern portion could not have radiated to the north. In 1865 Agassiz visited Brazil, of which he says, "During this period two vast caps of ice stretched from the northern pole southwards and from the southern pole northwards, extending in each case towards the equator and ice fields such as now spread over the Arctics, covered a great part of the temperate zones." He classifies the unstratified clay deposit of the Rio drift and its vicinity as genuine glacial drift, simply because it is unstratified, but the ochreous sandy clay of the Amazon valley, which is stratified, he claims was deposited by water held back by a terminal moraine, which he says then closed that valley from the sea. Unfortunately for this unique theory, although over forty years have elapsed, no other geologist has been able to relocate that terminal moraine. On the subject of Diluvial and fluvial deposits, the diluvial or stratified deposits of the Pleistocene, seem generally to be acknowledged by glacialists to be due to floods. James Geikie says, the wide and deep masses of Löss (brick earth) which characterize such valleys, as those of the Rhine and Danube. The considerable elevation attained by these deposits, and their vast extent. "The great bulk of the loamy deposits, I would assign to the action of vast inundations. I believe the same rule holds true for all the great river valleys of Europe." He also says, "these deposits are the results of the great floods that took place doubtless as stated, all through the glacial period."

Turning to this continent Prof. Dana says, "That a flood vast beyond conception was the final event in the history of the glacier (American) is manifest, in the peculiar stratification of the flood made deposits. Only under the rapid contributions of immense amounts of sand and gravel from so unlimited a source, could such deposits have been accumulated."

Dr. Dawson, however, goes further when he says, "I have not found either in the Laurentian region, or over the area of the plains, or in the Rocky Mountains, any evidence necessitating the supposition of a great northern ice cap—or its southern progress—to reach the 49th parallel a northern ice sheet would have to move up the long slope from the Arctic

Ocean, and cross the second traverse watershed, then after descending to the level of the Saskatchewan valley, again ascend the slope amounting to over four feet per mile, to the first traverse watershed and plateau of the lignite tertiary. Such an ice sheet moving throughout on broad plains of soft unconsolidated cretaceous and tertiary rocks would be expected to wash the surface with broad flutings parallel to its direction and to obliterate the transverse watersheds and valleys."

Dr. Croll's teaching differs from that of Agassiz, inasmuch as it involves the conclusion that there has been throughout geological time, an alternate glaciation of each hemisphere, ultimately caused by changes of eccentricity of the earth's orbit directly engendered by the greater amount of warm water forced into each hemisphere by the alternate greater potency of the trade winds north and south of the Equator. With Dr. Croll's allegation, that any material alteration of the direction of the Gulf Stream in the Atlantic and the Karo Siwo in the Pacific, would materially affect the climatic conditions, both on the European and American continent I have no disposition to question, but when he claims that the Gulf Stream, which is largely fresh water, (and is as he admits five miles broad by 1,000 feet deep) could be permanently affected by the wind and not by the Amazon and Mississippi rivers, which gave it birth, I claim that we are at least entitled to the Scotch verdict of "not proven." There is, however, one point where the doctrine of uniformity does not hold good between the two continents, namely that whilst in Europe the Pleistocene diluvials are largely marine, those of the interior and by far the larger portion of America are undoubtedly lacustrine. Agassiz also bears witness that the boulders of the American continent, are more rounded and that they show considerably less angular erratics than are to be found in the north of Europe. Thus we must admit that during the Pleistocene period there has been, not only a considerably larger fresh water lake area than at present exists, but that it had its outlet in Hudson's Bay in North America, and that the Amazonian Lake in South America had its exit further south. Also that this phenomenon could have resulted from a gradual rising of the continent on the Atlantic Coast and a corresponding depression of the Pacific Coast, or in other words a reversion of the action which is now going on. Dr. Croll claims that the so-called glacial period of the Pleistocene epoch took place, by alternations of 10,000 to 12,000 years approximately between 240,000 and 800,000 years ago and that there was also a previous period of alternating glacial phenomena between 980,000 to 720,000 years ago, having much greater severity, the alternations being the same.

J. Geikie claims from discoveries made in the Kent Cave, that prior to the Pleistocene glaciation, the Palæolithic man lived and died, in the caves of England and Northern Europe and that elephants, rhinoceroses,

hyænas, mammoths, and reindeer were his congenitors, and by a careful estimation of the time necessary to deposit the lime covering over their remains, he concludes that they lived and died in these caves about 240,000 years ago. That an icy cataclysm then took place, which either killed or drove them from their caves, that the earth or rather the northern part of Europe and the north-eastern part of the American continent, was then covered with a huge capping of ice, approximately 5,000 feet in depth for a long period, (Dr. Croll estimates from 10,000 to 12,000 years) towards the termination of this icy period, that there were numerous floods which built up, "the wide and deep masses of löss (brick earth) found in the valleys of the Rhine, Danube," and other rivers, in which remains of the Palæolithic man have also been found. Where these men lived in the meantime, we are not told, but eventually they all died, possibly several alternating glaciations took place, but eventually these long dreary alternating periods of ice and heat vanished. Then we find a new man, more highly civilized, called the Neolithic man, assume possession of the same cave dwellings, previously occupied by the then extinct Palæolithic man. So far so good, but how was the re-creation of this superior man accomplished, who was associated with the ox, sheep, dog and horse, and who used bronze instruments instead of stone?

Dr. Croll's arguments might be plausible, but for the undoubted fact that there have been considerable alterations of the earth's surface, from the Pleistocene epoch, to the present time. Herodotus tells of a priest of Solon informing him of a tradition of the destruction of a large continent by submergence, situated on an island beyond the pillars of Hercules. We also know that during the whole long period covered by the Mesozoic and portions possibly of the Palæozoic and the Cainozoic, in fact almost up to the Quaternary, the major portions of the American continent were dry land and particularly the Laurentian. During this time Europe, and particularly Britain and Northern Europe, were largely submerged, probably caused either by a sudden cataclysm, or by the gradual subsidence of land and the rising of seas, which would necessitate considerable changes of ocean currents, with resultant changes of climate. Thus even if we admitted Dr. Croll's postulations, we would find a very serious stumbling-block in the Laurentian rocks in the north-eastern parts of this continent, where we should find considerable evidence of Rochés Nivelées such as are common in Greenland, resulting largely from the prior glaciation between 980,000 and 720,000 years ago, as well as the latter, but less severe glaciation, between 240,000 and 80,000 years ago, both of which have been postulated by Dr. Croll, but these evidences are entirely wanting. The best barometer to test the character of a climate, is the fauna and flora, which lived whilst it prevailed. Cold-

blooded reptiles cannot live in icy water and semi-tropical plants, or those whose habitat is the temperate zone, cannot ripen and sow their seeds, under arctic conditions. Thus if the so-called glacial phenomenon was a recurrent event, we ought to find evidences of it in the palæontological record, failing this the entire theory necessarily collapses. On the contrary the flora and fauna exhibit no indications of violent changes, hot to cold and from cold to hot periods. The continuity of forces, particularly in the class of reptiles, from the carboniferous to the cretaceous period, is entirely opposed to the intercalation of glacial epochs, corresponding in importance to that of the post-Pliocene.

J. Geikie claims that finding the remains of the hyæna, the lion and the canary laurel associated with those of the musk sheep, reindeer and the polar willow is a proof of interglacial climates, but the evidence is that they lived together at the same time, for we find all over France, Germany and South Britain, reindeer bones mixed with hyæna, and gnawed by hyænas and we also find arctic willow leaves mixed with those of the canary laurel and the fig. This is only an illustration of the adaptability of those usually associated with northern climates, with those of a more southern origin, brought about by a change of climate, but certainly insufficient to have resulted in a glacial epoch. At the present time we have the reindeer and the tiger living together in Manchuria, but who would postulate a glacial period on such evidence?

The removal of the fauna and flora, of which there is positively no evidence that they were ever associated with an ice age; the impossibility of finding a single terminal moraine, except in the vicinity of high mountains, the proofs that till and löss are not terminal moraines, the proof that in high northern latitudes, the trend of erratics is northwards; the impossibility of an extensive ice cap on our western plains having ever existed, without leaving clear and distinct marks of its passage; and the proofs that vast floods have taken place during the Pleistocene epoch, practically reduce the supposed evidences of a glacial period and a single one at that (for otherwise had there been alterations indisputable marks would have been left at least on the Canadian Laurentian rocks) practically to the supposed erosive power of ice, erratics, till and striæ marks. In the northern hemisphere glacial action is wholly wanting from the White Sea eastward to about the vicinity of the MacKenzie River. This is generally conceded. Also, since on the fringe of the Arctic Ocean the trend of boulders is northerly, it follows, that it could not have had a pressure from the pole as postulated by Croll and Geikie, but that its summit of action must have been considerably to the south of the Arctic Ocean, that is, if it ever existed at all.

Mr. Oldham says, "that under a pressure of cohesion of its own substance 370 feet high, ice must yield and that no slow pressure greater than an equivalent to that depth of ice, could be transmitted by ice, while under a pressure of 960 feet of its own substance it would be crushed." He then makes a careful estimate of the pressure required to excavate the Lake of Geneva and finds that it would require a pressure of nine miles of ice, to force a glacier en masse through and out of the lake. This is for solid ice, but with névé it would be little or nothing. Whymper says, "When water is in the form of a glacier, it has not the power of making concavities and working upon surfaces, which are not opposed to the direction of the current. It leaves marks that are readily distinguished from those produced by torrent action. The prevailing forms resultant from glacier action, are more or less convex. Ultimately all angles and almost all curves are obliterated and large areas of flat surfaces are produced and can be traced by means of bosses of rocks termed Rochés Moutonnées. They owe their peculiar form to the grinding of ice, but they were blocked, anterior to the formation of the glaciers, the hollows were not so much affected, but the eminences were ground down, the depressions in modelling remained, but the parts in relief were taken away." At several places in the Görner glacier one can get underneath and see the ice bridging over hollows. When a glacier passes over rough ground, it is supported upon a number of points and bridges many hollows, the parts touched are alone abraded, while the hollows escape. The depressions which are not opposed to the direction of the glacier's motion, if anything like perpendicular to it, remain and will continue to do so, becoming less and less, till the whole bed of the glacier has been reduced to a plane surface." Such surfaces are common in Greenland and are called Rochés Nivelées.

Prof. Niles in 1878 went a considerable distance under the Aletch glacier, saw a boulder through a tunnel of blue ice, which was continued as a deep furrow in the under surface of the glacier, for at least thirty feet from its beginning. As this was produced by the ice moving over and beyond the boulder, it was evident that the ice was moving more rapidly than the boulder. He saw other instances of the same kind and argues that the movement of boulders in a glacier is one of extreme slowness, even when compared with the motion of the glacier itself. Mr. Ball argues that "a glacier slides over concavities without touching them and applies all its grinding power to the convex portions of its bed, consequently valleys excavated by glaciers, should show a uniform model. Instead of this many of the Alpine valleys, consist of a series of level basins, rising in steps as we mount them and connected by gorges which are much narrower than the basins they link together. This is conclusive that

some agency other than ice, must have directed the original formation of valleys of this type." Similarly Mr. J. Geikie says, "he cannot see his way to account for the vertical cliffs surrounding cirques, by invoking ice action," while Mr. Jukes Brown refers to a cirque he saw in Egypt, where ice action is impossible and which he calls a rain gorge.

Murchison says regarding fiörds, "Where in any icy track, is there evidence that any glacier has by its advance, excavated a single foot of solid rock? In their advance glaciers striate and polish, but never excavate rocks. The plain and unmistakable geological conclusion, is that wherever the earth's crust was broken up from beneath, it necessarily underwent great transverse cracks, which opened into fissures and caverns. The true origin of all such great transverse fiörds or cañons, or in short of all abrupt fissures in hard rocks, into which bays of the sea enter, or in which rivers flow, must be referred to original breaks in the crust, of which the waters have taken advantage and have found the most natural issue."

Now as to Greenland, to judge from the period during which we have records, it seems clear, that while the land has been rising from the sea, it has been growing colder, glaciers have increased and ice has encroached upon the old dwellings and hunting grounds of the Esquimaux, which in many places are no longer habitable. Dr. O. A. L. Mörch examined a collection of shells from North Greenland, found them partly belonging to species still living there and partly to more southern forms. Dr. Rink speaking of Jacobshavn fiörd says, early maps show it as a sound uniting the north Atlantic with Baffin's Bay. It is now known only as a deep fiörd, filled with huge icebergs. Tradition amongst the Greenlanders is that formerly it was less obstructed with ice and good hunting ground. This is proved by numerous remains of old dwellings. Walrus no longer enter the fiörd, even the bear is scarce, but bones in Kitchen Middens prove that those animals were once abundant. It is difficult to conceive how it would be possible to secure such a surface slope, as would move ice from the Laurentian highlands 700 miles away over the prairies, or which could traverse the deep basin of the Baltic and 600 miles to the south of it, which would fill the North Sea and overwhelm Great Britain in its icy folds and transport Finnish and Swedish ice to Central Russia and the Carpathians without at the same time so completely burying the whole country in ice, as to prevent any boulders from falling upon it from exposed rocks? There are no moraines in Greenland except where the Nunataks or exposed rocks project above the ice. Where it is unbroken like those districts traversed by Nansen, there are no moraines. Ice moving over level ground would have no crevasses, by which surface blocks could be dropped into the glacier and therefore there

could be no drift, for distribution by the ice sheet. None dispute the fact that in Greenland and the Antarctics, there are vast accumulations of ice; but who will admit that it can move in some extraordinary way independent of gravity and quite differently from ordinary glaciers? Croll and Geikie knew this, but they postulated that Greenland and the Antarctics are composed of low lying lands, which subsequent explorations have proved to be incorrect. Dr. Croll virtually admits that we can nowhere even in polar latitudes, find masses of ice moving over level plains, still less ascending steep gradients, at a distance from the declivities, which give impetus to forward movement. He explains this by saying, that in the Arctic and Antarctic regions, the seas are so deep that the power of flotation is called into action close to the existing coasts, and that the ice sheets have been thus broken up. Sir J. Ross' soundings close to the face of the southern ice sheet prove conclusively that the Antarctic ocean is shallow, deepening to 1,140 feet at a distance of 120 miles north from the ice barrier and is therefore too shallow to float such an ice sheet as Dr. Croll postulates. Again if an ice sheet is an eroding instrument pressing with enormous weight upon its bed, polishing and striating it, how can it, at the same time deposit a layer of soft débris underneath its foot? Also how can we explain the existence of shells in so called glacial beds, sometimes at low levels and sometimes at very high levels, or for the movement of erratics up hill, or the presence of Scandinavian boulders, in the drifts of East England, or how can we account for the fact, that the drift of boulders and the direction of the striæ, are not always consistent with one another, nor the occurrence of cross hatching amongst the striæ, or the fact that the striæ marks occur in many cases in apparently continuous lines, traversing a wide expanse of country, utterly disregarding its contour and drainage. If we follow our water courses, or wherever there are evidences that water has run, we find striæ marks, boulders and till are most prolific and the further we get away from these watercourses, the less we find. Mr. Hopkins says, "Blocks cannot generally be rounded by attrition, when floated on an iceberg, or carried on the upper surface of a glacier. A small portion of those brought down by glaciers are rounded by being rolled, but this is rough grinding and all specimens I have examined at the termination of a glacier, wanted that more perfect smoothness of surface which distinguishes a water-worn boulder." Alluding to Russia and the Ural Mountains Murchison says, "A vast portion, by far the greater part of this drift, has we think been transported by aqueous action, consequent on powerful waves of translation and currents occasioned by relative and often paroxysmal changes of sea and land. Now we are sustained by the reasoning of mathematicians, who show us, that with sudden vertical elevations, each not exceeding fifty feet in the case of an ocean of 300 or 400 feet in depth

(and might not corresponding depressions produce the same) bodies of water have the power of hurling on enormous blocks, sand and gravel to vast distances and over considerable inequalities, we are relieved from one of the great difficulties opposed to the rational explanation of the position of a very large proportion of this drifted material. Whatever may have been the period of their action, such aqueous débâcles, have probably formed many of the conglomerates of previous ages and with the help of ice floes, much of that foreign drift, of which we have already treated."

Prof. Tyndall says, "the creation of a glacier, or a glacial period is really a process of distillation on a great scale, in which a sufficient supply of vapour in the air, is quite as important a factor, as a sufficiently powerful condenser to convert it into snow and ice, and the process of making vapour and condensing it, must be going on at the same time in different areas. We cannot condense the vapour made in summer, by the winter's cold, because we cannot store up that vapour. Vapour is lighter than air and air charged with vapour immediately rises, until it reaches a higher altitude, there it finds greater cold and inevitably discharges its moisture, generally in the shape of rain. This causes the great rainfall in the tropics. In the supposed case, therefore, of a hotter if shorter summer, would no doubt evaporate more water per day, but vapour thus made would descend in the shape of rain long before the winter came, and when it came there would undoubtedly be greater cold to condense what vapour there was. So that the amount of vapour left in the air would be very slightly, if any more, with great eccentricity than with a small one and there would have been little or no appreciable effect on the snowfall." Recurrent glaciation should show traces in the earlier formations, but James Geikie says, "We look in vain for Cambro-Silurian rochés moutonnées and boulder clay or moraines." The same may also be said of all the succeeding formations in the Palæozoic and Mesozic, besides there are many indications of considerable heat, that would preclude the possibility of any glaciation during those epochs.

Prof. Andrews speaking of the gravel deposits of the United States, says, "These gravel hills are often sharp and conical and interspersed with deep valleys without outlets (potash kettles). . . . . It would seem an unavoidable inference, that our drift of this region, not only came from the north, but it came in a vast sweep of water, deep enough to cover gravel hills 800 feet high and with velocity enough to throw such coarse material into lofty and steep summits." T. Bergmann so far back as 1769, noted similar phenomena in Sweden, which he calls (Giants, Cauldrons). He claims they are "due to the working of stones arrested by some impediment and then made to turn round by water." He quotes one which

was "thirty years old and its actual growth had been watched by Nordenskiold."

Perched blocks cannot be well accounted for by any ice theory, as they are balanced on comparatively small bases, which preclude the possibility of their having been dropped or rolled. Generally they are found in the neighbourhood, or on the flanks of hills, where their presence can only be attributed to a débâcle. Sharp points or ridges projecting from the general surface, would naturally arrest them as they were being violently swept along by the flood, and as the wave subsided, probably gently, it would leave them supported through the line of their centre of gravity, leaning against or perched upon these arresting projections.

Sir James Hall describes a somewhat similar phenomenon known as crag and tail. "When an obstacle whose height is equal or greater than its breadth, stands in the way of a running stream, it generally causes a stagnation, on the side towards which the stream is flowing, a deposition is formed of the transported substances constituting a tail or prolongation, which extends in the direction of the stream, by a gradual descent to the distance frequently of eight or ten times the height of the obstacle, while a hollow or depression is frequently caused on the other side of the obstacle by the accelerated motion of the stream there." If we examine the bed of any rocky mountain stream, we find the largest stones at the greatest altitude and we find them reducing in size as we descend the stream. We see it widening out and becoming more sluggish until ultimately it deposits nothing but sand and mud. Now, if we postulate a sudden potential diluvial wave, such as has been described by Murchison or such as have recently taken place at Samoa, denuding and carrying along with it, every obstacle that obstructs its passage, passing over hills and dales and tearing along the sides of the highest mountains, then gradually subsiding after having reached its maximum velocity, we should find the débris deposited by it, large and small stones irregularly mixed with sand and clay without any general stratification. We should expect to find the crag and tail phenomenon, also äsar or whale back ridges, just as we find till or boulder clay heterogeneously mixed (that has sometimes been mistaken for moraines). We would also find boulders of various sizes (the largest stopping first) rounded, scattered and fanwise, in fact a reduplication of erratics. We would also find striæ marks caused by the rapid passage of these boulders, stone and sand not only upon the rocks which have been passed over, but upon the boulders and stones themselves and we would find these striæ marks sometimes in straight continuous lines, sometimes slightly deflected by opposing obstacles, which also results in cross hatching, where boulders have been diverted by impact, or some other cause, across the current of the débâcle.

But we may look in vain for any indications of the agency of ice, such as the rounded and polished surfaces of Rochés Moutonnées or the flattened and more highly polished Rochés nivelées, for terminal, lateral or medial moraines, such as we find in Switzerland, for straight striæ markings with little or no lateral deviations, and particularly without cross hatching, or for boulders with flat sides and scratches upon them. Thus I claim that the glacial theory which in 1871 was accepted by Geikie as "the only theory which seems to satisfy all the requirements of our present knowledge," has lived its day and with our now maturer knowledge, should be superseded by that of water, acting in sudden potential débâcles, which is the only theory that I know, which seems to satisfy our present requirements, and which is thoroughly in keeping with the well known power and action of that element.

CLIMATE OF YUKON TERRITORY.

By R. F. Stupart, Esq., Director of the Meteorological Service of Canada.

[*Read 15th December, 1906.*

Meteorological observations were begun at Fort Constantine, Yukon Territory, in November, 1895 by Staff Sergt. Hayne of the Royal North-West Mounted Police. In September, 1897, the instruments were removed to Dawson and observations were continued voluntarily by the police and by the Commissioner of the Yukon until 1900 when the duty of observing was taken over by the Meteorological Service and an unbroken record has since been obtained at Dawson. Other records in Yukon in the possession of the Meteorological Office are as follows:—Selkirk from November, 1898, to November, 1899; Tagish Lake from August, 1898, to August, 1900, and White Horse from November, 1904, to the present time. In addition to these Yukon stations, a station at Atlin, B.C., but twenty-five miles south of the boundary, was opened by the Meteorological Service in August, 1905, and will be of assistance in determining the climatic conditions of southern Yukon. A study of all available data leads to the conclusion that while Dawson is further north than White Horse, the climate of the former place is much more suitable for agricultural purposes than that of the latter, and in general that the northern and eastern portions of Yukon have a warmer summer climate than have the more southern portions. This is probably in part owing to the fact that the former are at a lower level than the latter and in part to the fact that southern districts are much nearer the ocean from which the westerly winds blow, while in the north the westerly winds are from the broader land area of Alaska, and the country generally is protected by mountains ranging from 5,000 to over 10,000 feet. The mean summer temperature at Dawson is fully 5° higher than at either White Horse or Atlin, B.C., and while frosts seem to be frequent at the latter places in both June and August and occur occasionally even in July; in the former both June and July are practically free from frost and it is not until about August 20th that there is much danger and very frequently September opens with as yet no frost. After the close of August the downward trend of the Dawson temperature curve is very rapid and the

winter months are probably between 15° and 20° colder than at White Horse. A summary of the general conditions of each month at Dawson will probably give the best idea of the climate.

January—The average mean of this month at Dawson is about −24° and the temperature seldom rises above zero; in some years never. On twenty-one days or about two days in three the temperature falls to −20° or lower; on eleven days or about one day in three it falls to −40° or lower.

The days of −50° or lower are more variable in number; the average is about one in six but in eleven years there have been some Januarys with fourteen or fifteen days −50° or lower, while there have been others with not one or only one −50°. A spell of −60° and lower seems to occur every few years. The lowest temperature on record is −68° in 1901. The two coldest Januarys were those of 1896 and 1905, the former with an average temperature of −38° and a minimum of −65°, and the latter with an average of −34° and a minimum of −66°. The mildest January with a mean of −15.5° and minimum of −50° was that of 1901.

At Selkirk the conditions during the month are very similar to those which obtain at Dawson. At White Horse the mean is about 20° higher than at Dawson and the monthly range of temperature is more pronounced; comparatively mild days occur occasionally and extremely low temperatures do not occur so frequently, although some of the lowest dips reach about the same reading as that recorded at Dawson. At Tagish Lake the mean is about 15° higher than at Dawson and cold dips not so severe.

February is usually much milder than January, the average mean temperature being about −12° or 12° warmer than January. The coldest February of which there is record was that of 1896 with a mean of −23° and the warmest that of 1897 with a mean of −3°. In the former month −60° or lower was recorded twice, but in no other February excepting that of 1903 did the thermometer record as low as −50°. In 1897, −31° was the lowest; this February was remarkable also from the fact that the temperature rose above the freezing point on sixteen days, whereas in no other year was 32° reached. On the average there are three days on which the temperature does not fall to zero; it falls to −20° on fourteen or fifteen days and to −40° or below on four or five days. Other stations also show that February is not as cold a month as January.

In March the monthly average at Dawson is 5°; on an average zero is reached on nineteen days and −20° on eight days, while −40° may be recorded, but it is unusual, and −50° has not been recorded since March, 1897. The temperature in this month frequently rises above 32° and 50° is occasionally reached. The more southern stations show a mean temperature about 10° higher than Dawson.

April may well be termed the first spring month as there are few days on which the thermometer does not rise above 32° and 50° is occasionally recorded. The average mean of the month is 28° and in some years the temperature does not fall to zero. The precipitation is usually in the form of snow, but rain sometimes falls. In this month the average temperature is very approximately the same throughout the Yukon.

May has an average mean of 46° at Dawson and there are few days on record on which the temperature has remained below freezing all day; 50° or higher is reached on twenty-four days; 60° on nine days and there are many records of 70°, notably in the years 1905 and 1906 with ten days of 70° in the former and seven in the latter. The average date of the last frost is the 19th.

The ice on the Yukon at Dawson usually breaks up between the 15th and 20th, but not until a fortnight, or three weeks later, on Lake Laberge. The season is now further advanced in the north than in the south and it is not until the end of August or early September that the mean temperature is again as low as at White Horse or Tagish.

June is a perfect summer month and with practically no darkness and on fair days nearly twenty hours of bright sunshine, vegetation advances very rapidly. Frost, while not unknown in this month, is quite unusual. The average daily maximum temperature is 70.5° and the daily minimum 45.2°, giving an average mean of 57.5°; 70° is on the average reached or exceeded on sixteen days; 80° or higher on four days and 90° was recorded in June, 1899.

July weather in Dawson is quite fairly comparable with that in the same month in southern Alberta and with the longer days growth is probably more rapid in the former locality than in the latter. The average mean temperature is 60.4° with an average maximum of 72.7° and an average minimum of 48.1°. There are very few days on

record when the temperature did not reach 60°, and 70° is reached on the average twenty days in the month; 80° is reached on six days and there are a few instances of 90°.

The August mean temperature is 54.5°. The month opens warm but a very decided downward trend of the temperature curve occurs after about the 15th, and there seems to be a decided danger of frost after the 20th. It is still quite the early autumn when the temperature of Dawson drops below that of White Horse and the southern Yukon generally, and the difference as has been shown becomes more and more pronounced until after midwinter. With a mean temperature of 41.6° in September and an average daily minimum little above freezing, autumn is soon well advanced in Dawson and the temperature sometimes falls below 10° before the month closes.

October is winter with a mean temperature of 24.1° and zero readings well before its close. Towards the end of this month ice begins to run in the Yukon, but it is not until about ten days later that the river sets fast.

November mean is −1°; the temperature very seldom rises to the freezing point; on twenty days it falls below zero and on seven to −20° or lower with an occasional dip to −40°.

The December average mean temperature at Dawson is −10°; the highest mean in ten years was zero and the lowest −18°; readings below −40° are usually recorded on about three days each December and −50° may be reached; there are few days on which zero is not recorded. The White Horse average temperature is nearly 20° higher than at Dawson.

Short as has been the temperature record at Dawson, that of precipitation has been shorter, covering a period of but five years at Dawson and much less at other stations.

As an approximation however, the annual snowfall in the Yukon is about 52″ and the rainfall 7.5″ July, August and September are the months of largest rainfall, each averaging a fall of something under two inches, much of which comes with thunder storms. Most of the snow falls late in the autumn but occasional light falls occur up to April or even May.

The following are the hours and minutes on the 21st day of each month that the sun is above an unobstructed horizon in the latitude of Dawson; January, 5^h, 55^m; February, 9^h, 15^m; March, 12^h, 10^m; April, 15^h, 38^m; May, 18^h, 51^m; June 20^h, 48^m; July, 18^h, 54^m; August, 15^h, 39^m; September, 12^h, 10^m; October, 9^h, 8^m; November, 5^h, 50^m; December, 4^h, 1^m. As a matter of fact, however, Dawson together with many other of the centres of habitation is so much closed in by mountains and hills that the actual period of sunshine is less than indicated by the figures.

It is claimed that there is little wind at Dawson in winter and this is to a large extent true. The cyclonic areas which enter the continent from the Pacific pass far to the southward of latitude 64, hence barometric gradients are not usually steep.

DO WE NEED A FORESTRY COLLEGE?

By Thomas Southworth, Esq.

Read 13th April, 1907]

College training seems to me to be of two kinds: that which tends to broaden and develop the mental powers of the student, and that which imparts the special knowledge necessary to a profession by which he expects to earn his living.

The successful college must impart either culture or "bread-earning" knowledge, and where eminently successful, both.

Although the student of forestry in a thorough study of his profession must to some extent receive the training that broadens and develops, must follow studies that tend to culture of the mind, forestry is primarily a "bread and butter" profession, and if a College of Forestry is to be a success, its graduates must be able to secure lucrative employment as foresters. Some men may, of course, undertake a course in forestry for the mental training afforded, or because of their interest in the problem of forest perpetuation, and without intention of adopting forestry as a profession. Such men will be rare however, and speaking generally, men will undertake a college course in Scientific Forestry as a means of earning a living.

Upon the question of any considerable number of foresters securing such employment in Canada depends the success and the need of a College to train men for the profession.

Do we need trained foresters, is a question easily answered. We do. That the men or the interests that would be profitably served by them are all prepared to agree with me in this is by no means certain, however, and unless the men controlling the forested lands of Canada can be brought to this point of view, I cannot see that we have any particular need of a College of Forestry. There are several excellent Schools of Forestry in the United States. The training there is such as to fit men to cope with forest problems much the same as exist on this side of the international boundary, and if but few openings for foresters offer in this country, we have no need to expend the money and the effort to train the few men required to fill them.

It is apparent, therefore, that our need for a College of Forestry depends on the probable demand by employers for the services of its graduates, and a canvas of the situation in this regard will be of interest. In this I shall refer to Ontario with which I am more familiar than with the rest of Canada.

The forest lands of Ontario for the purposes of this discussion, may be divided into three classes: those under a practically perpetual lease to lumbermen; those under lease to lumbermen for a fixed period; and those still held by the Crown free from lease or "license to cut" as it is usually termed.

The first and second classes comprise about twenty-one thousand square miles, or about thirteen and a half million acres of forest lands. On some of these areas the encroachments of agricultural settlement will some time cause the abandonment of the lease or license, but by far the greater part of this area is not adapted for agriculture, and will or should continue to be timber producing. These lands, as stated, are under license to individuals or companies, and the nature of the lease is such as to leave the control and management of them almost wholly in the hands of the lessees, subject to the payment to the State of a nominal ground rent varying from $3.00 to $5.00 per square mile, annually, and a stumpage charge of $1.00 to $2.00 per thousand feet as the timber is cut. The State may or may not some time receive a greater share of the value of the timber on these lands than at present, but in any event the non-agricultural areas under license should be properly worked with a view to perpetual recurrence of crops of the most valuable sorts of trees. To this end technically trained men are necessary.

The men or companies operating these limits employ many thousands of men with a very large number of superintendents, rangers and foremen.

In 1903, with a view to ascertain the chances of employment for forestry graduates, I wrote to a number of the leading lumbermen of the Province, asking if, in the event of a properly equipped College of Forestry being established, they could find employment for its graduates. Replies were received from all of them, and there was a striking unanimity of opinion among them to the effect that the graduates of a College of Forestry would be of little use to them owing to their want of practical knowledge in the bush, sawmill and lumber yard.

I am glad to be able to say that one of these men has so far changed his opinion as to tell me recently that he proposed to engage a forester

to go over a newly acquired limit and prepare a working plan for operating it on the basis of removing yearly only the amount of timber that would equal the annual growth. This is very encouraging, and a sign of the times, but it is an isolated case, and cannot be taken to mean that the lumbermen are going to engage foresters in large numbers.

When the graduates in forestry are able to demonstrate their ability to increase the profits of the lumbermen, they may look for profitable employment among them, but not before; and this demonstration must be made in Ontario, or at least in Canada. If they can show that they are no mere theorists, but practical, well trained men, capable of directing large lumber operations economically, they will be assured of employment by the private holders of timber lands, who are business men and willing to pay for efficient service.

I doubt very much if there is any business in this country carried on with so little regard to economy, with so much waste, as the great lumber industry. The profits of the business, owing largely to the low first cost of the standing timber, have been handsome, and the lowest possible cost of production has not been so imperative in this as in most other industries. Waste of timber, of supplies and of labor has characterized the business from the earliest days of lumbering in Canada. Until quite recently good pine timber was used to make roads and shanties, when less valuable trees were equally available. Felled trees containing much good material but defective in part were left in the bush to rot or add to the material for forest fires. Food and other supplies were frequently left to spoil. Delays in driving logs down stream owing to poor management, have added to the cost of production, and in many ways the lumbering business has been conducted in a reckless manner that very few businesses in these days of keen competition could stand.

This state of affairs has been due to no lack of desire on the part of the limit holders to make as much money as possible from their timber holdings, but their operations were conducted on a large scale, often at great distances from the head office, and the proprietors had to depend on the work of the men whose whole training had been received under similar wasteful conditions. In most cases these men are not observant except in one beaten path. They learned, in the gradual promotion from a lumber Jack or shanty man to foreman and perhaps to superintendent, to estimate the quantity of timber a given tree would make, and to make a good guess at the quantity of standing merchantable pine on a given area, but their methods of removing this timber are in most cases those followed by their predecessors with little change. The damage done to young timber in felling trees and which could be largely avoided, they seldom

take into consideration. In fact the trees too small to make merchantable timber are usually regarded as of no value. A prominent lumberman told me a few years ago that he had incurred the pitying contempt of his foreman by giving orders that they should not use young pine trees for roads and shanties when balsam, poplar or other less valuable trees could be got for the purpose. Men with their training are apt to have very little idea of the rotation of the forest crops, or the reproduction of trees or many other things useful to know in forest operations involving a long term of years.

To illustrate: A few years ago I was travelling over a timber berth with the forest superintendent of a large lumber company. As we walked through the bush I picked up and examined quite a number of white pine cones. In answer to his inquiry I explained that I was trying to satisfy myself whether all the seeds had dropped out before the cones fell from the tree or otherwise. He expressed great surprise on learning that the cones had contained seeds, and said he had seen those things in the bush often, but never knew what they were. It had never occurred to him to consider how the trees grew, whether from seed or "spontaneous generation." It was sufficient for him that the trees were there to be cut.

Now, this man was active, intelligent, and held a very responsible position. He knew his business, as he had learned it, well, but I submit that this man with the practical knowledge he possessed, plus a scientific training, would have been of far more value to his employers than he was or is.

That lumbermen will ultimately recognize this, I have no doubt, but they will need to be convinced by the actual work of trained foresters. I do not pretend to say that the method of lumbering so far followed by Ontario limit owners has not been on the lines of good forestry from the point of view of their financial interests. Practical forestry is simply business, and in the case of these timber licenses issued from year to year, liable to be cancelled if the land was needed for settlement, it was quite natural and wise that the lumbermen should remove all the timber, mostly paid for in a lump sum in advance, as cheaply as possible and as thoroughly as they could. It was liable to burn up, the license might be cancelled, interest charges on the money paid in advance for the timber accumulated, and the lumberman followed proper forestry methods in cutting his timber off without much thought of the future.

What was good forestry for the lumberman, however, was not wise forestry practice for the State, and let us hope that some time even on this class of timber land forestry methods more in the joint interest of the

State and its lessee, the lumberman, may prevail. With security of tenure the lumberman would be equally interested with the State in conservative lumbering, and could afford to accept cutting regulations to that end.

If, however, the lumbermen will not employ foresters, and thus enable them to prove their usefulness, how are they to be convinced, may well be asked.

I have previously stated that our forest lands were controlled partly by the lumbermen as lessees, and partly by the State. By far the greater part of our forest lands are held by the State free from license to the lumbermen. Much of this territory does not contain presently merchantable timber, but a very large area does, and I submit that the first large employer of properly trained foresters and forestry students should be the State. Under the Forest Reserves Act of 1898, over ten million acres of forested lands, unsuited for agriculture, have been set aside as permanent forest reserves. These reserves will doubtless be added to from time to time as the unfitness for agriculture of other areas is proven. I have elsewhere expressed the opinion that no less than forty millions of acres of similar non-agricultural land in Ontario should be placed in reserves.

The reserves so far created contain a very large quantity of standing timber, thousands of millions of feet, some of it not yet fit to cut, some of it already over-mature and past its prime. Except in the case of two small reserves of cut-over land, no pine timber has been sold in these reserves, and no policy for their exploitation adopted by the Government. Aside from patrolling them in the dangerous months for fire protection, no work has been done upon them.

In one of these, the Temagami reserve, important discoveries of minerals have recently been made; there will be a large number of mining prospectors travelling it this season, and it is probable that some definite policy governing mining development and protecting the State's interest in the timber will be adopted in the near future. The Legislature has just voted $5,000 for "estimating" the Temagami reserve. This I take to be for the purpose of beginning the systematic examination of the reserve, and I presume will include not merely an estimate of the merchantable pine, but a general topographical survey and an estimate of the various kinds and quantities of timber in order that working plans for the systematic handling of this forest for a long term of years may be prepared. To do this work trained foresters will be needed, and they do not seem to be at present available.

Aside altogether from the forest reserves, the Government has an

interest in the timber under licenses to lumbermen, and derive considerable revenue from this source. For the collection of the stumpage dues on the timber cut under these licenses the Province is divided into various districts or agencies in charge of a Crown timber agent. Attached to each agency are one or more bush rangers, and in each logging camp a timber scaler or culler, as he is termed in Ontario. The Crown timber agent is usually paid a yearly salary, and the rangers a per diem allowance when employed. These men are paid by the Government. The culler, the man who measures the logs or timber as cut, and on whose returns the dues are paid, is licensed by the Government after passing an examination, is employed and paid by the lumberman. In order to check these returns and to see that the cullers are not making measurements unduly favorable to the lumbermen who employ them, the bush rangers make occasional tours of inspection among the various camps, and take sample measurements.

Before offering timber stumpage for sale, the Department of Lands and Forests causes the territory to be examined, and an estimate of the amount of standing pine prepared, to gain some idea of its value, and bush rangers are employed for this purpose. Altogether a very large staff of men are employed directly and indirectly in the bush by the Government, aside from several hundreds of fire rangers employed, some wholly by the Department, some jointly by the Department and the lumbermen.

I do not wish to convey the idea that these men should all be graduates of a College of Forestry, but some of them might well be, and the others could be much improved in effectiveness by instructions they could receive from properly trained foresters.

That forestry graduates would be so employed is reasonable to expect. In 1898 there were not half a dozen technically trained men employed in the United States Forest Service; there are now about nine hundred. Of these two hundred are forestry graduates, and more would be employed if they were available.

If graduates of a Forestry College can demonstrate by their work for the State that they are practical men, and know their business, they may look for positions among private timber holders who usually pay higher salaries than the State.

This has already happened in two instances recently. Dr. Judson F. Clark, of the Ontario Service, and Mr. Roland Craig, of the Dominion Service, both graduates of Forestry Colleges in the United States, have

left the public service for more lucrative positions with large lumber concerns in British Columbia.

It is not expected that the College of Forestry will turn out men who would be immediately competent to take the management of large lumber operations. The School of Practical Science does not pretend to turn out well equipped engineers with the necessary practical experience. In the same way graduates of the new College of Forestry must acquire much of their practical knowledge after they leave college, but unless I am much mistaken in my estimate of the gentleman who is to be Dean of the Faculty of Forestry, the graduates of the Ontario College of Forestry will take rank with those of any other College on the Continent.

The need for trained foresters in Ontario is already apparent. It will become more apparent as it becomes generally recognized that a forester is primarily a lumberman, though a lumberman may not necessarily be a forester. A forester is a farmer whose crops are trees. He is not a sentimental theorist, but a business man engaged in a business that requires a technical knowledge of natural conditions affecting his crop, and whose plans in the sowing and reaping of his crop must extend over long periods of years. So long as we merely harvest the matured crop of trees nature has provided for us, the scientifically trained man is not so necessary, but when we reach the stage where future crops must be provided for, a knowledge of the nature of forest growth and reproduction is imperative.

In the policy of separating the agricultural from the non-agricultural lands, keeping the latter for the perpetual production of timber, now adopted in Ontario in the creation of forest reserves, we have reached that stage, and there is every reason to expect that properly trained foresters such as we expect Dr. Fernow to turn out, will not be without employment in this Province.

IGNORED DISTINCTIONS IN ECONOMICS.

By W. A. Douglass, B.A.

[*Read 28th April, 1907*]

My object in this paper is to show the relationship between wealth and value, and also, to point out that value is not simple, as is so commonly taught, but that it is of two kinds, the increase of value in one case indicating an increase of wealth, and an increase of value in the other case indicating an increase of poverty.

When the farmer sows a bushel of wheat and reaps twenty bushels, when the clothier multiplies the supply of garments or the mechanic multiplies the quantity of implements, there is a multiplication of value and also a multiplication of wealth concurrently. It is to this relationship of wealth and value that the attention of the student has been principally confined, so that many writers on this subject have concluded that wealth and value are identical. In the minds of the multitude, this belief is almost universal. So far has this doctrine gained vogue, that a vast number of the writers on economics have fixed on value as the distinguishing characteristic of wealth, and have consequently defined wealth as consisting of "those things which possess exchange value."

A further examination, however, will show not only that this is a fallacy, but that it is a fallacy fatal to a proper understanding of economic science.

Sometime ago I found a most interesting document in the Buffalo Public Library. It was a newspaper, published during the siege of Vicksburg in June, 1863. The printing was on the reverse side of some wall paper. In one paragraph the editor was denouncing, in language most vituperous and scorching, the manner in which certain parties were doling out provisions at most extortionate rates—flour e.g. at a dollar per pound, say two hundred dollars per barrel. No one would for one moment specify this increase in value as an increase of wealth. And, when the siege was over, and the price of provisions had fallen to their normal figure, no one would dream of calling this decline in value a diminution of wealth.

When the opening of the Suez Canal reduced freight rates from Bombay to London from 32 cents per bushel to 16 cents; when the opening of the Erie Canal reduced the cost of conveying a ton of freight from

New York to Buffalo from $100 to $10, and when the introduction of the Bessemer process of converting pig iron to steel reduced the price from $300 per ton to $50 per ton, this reduction of value, instead of indicating a reduction in the supply of wealth, indicates the very opposite. Indeed, we may conceive of the improvement in the method of production being carried so far as to eliminate value altogether. This is illustrated in the case of water in Australia, reported by Jevons, where, during a drought, the price arose to seventy-five cents per pail-ful. On the return of the rains, the price fell to zero. With the increase of drought the value increased and with the increase of wealth the value disappeared, and some writers, tied down by a fallacious definition, actually teach that this elimination of value means the disappearance of wealth altogether.

When we say the crop of wheat has multiplied twenty fold and that the wealth and value have also increased in the same ratio, this does not mean that any one bushel has become more valuable; but that there has been a multiplication of valuable units. In the case of the siege, however, there was no increase of the number of units; but there was a distinct increase in the value of each unit. The first was a value of "extension" meaning a multiplication of the units, or an increase in the quantity of valuable utilities; while the second is a value of "intension," meaning, not an increase in the number of valuable units, but a higher value for each unit.

Many writers have noticed this increase of "scarcity" or "intensive" value as a matter of little importance, as referring only to some scarcity of master-pieces in painting or treasured heir-looms. If that were all, it would not be worth the time spent in discussing it; but when we notice that it relates largely to the value of mines, forests, water-powers, land and franchises, and that the value of these natural opportunities is probably as great as the value of the products of industry, then we see that it is not a matter of merely trifling import.

As nearly all our legislation, whether relating to the rights of property, the distribution of wealth, or the imposition of taxation, is based on the assumption that wealth and value are one and the same, and that values are wholly of one kind, we may then see that the correct interpretation of this question is one of the most important, for the proper government of humanity, the harmonious relations of society, and the success of our civilization.

This difference of values, the one concurring with an increase in wealth, the other concurring with the diminution of wealth, has puzzled more

than one writer on this subject. The statement made by the French author, Gide, is very interesting. "Suppose," he says, "that by some lucky miracle all products were to be multiplied so as to become as abundant as spring water, should we not have to regard this as an increase in wealth, nay, as the very climax of wealth? Yet all things, on account of their superabundance, would have lost all value, having no more value than so much spring water." He also says further: "This is the question which J. B. Say thought to be the most difficult in Political Economy, and which he stated thus: 'Wealth being made up of the value of things which are possessed, how can it come about that a nation will be richer by lowering the price that is asked for these things? Prudhon, in his Contradictions Economiques, raised the same question and defied any serious economist to answer it.' "

Smart, in his Theory of Value, page 13, gives a partial answer to this as follows: "Certain goods we have from nature, without money and without price, and the incessant effort of the industrial world is in the direction of bringing all goods into this category. The effort to cheapen production is nothing else than the effort to increase utility at the expense of value."

It is not to be wondered at that J. B. Say and Prudhon found themselves in an economic *cul-de-sac;* for they tied themselves up in an utterly fallacious definition, confounding wealth with value.

Division of labor and exchange are inseparably connected as the blades of a pair of scissors. Just as inseparably do exchange and value belong one to the other, the correct ratio of exchange being the proper value. Two conditions are essential to value, utility and scarcity. Value, therefore, may come in two different ways, either by adding the utility to something that is scarce, or by making something scarce which already has the utility. But these two conditions are not of like character as an addend and an addend; but are opposites as an addend and a subtrahend, or as wealth and poverty. To produce a locomotive is to add utility where the condition of scarcity already exists, therefore, the locomotive has value and this is an increase in wealth. When, however, water, which already possesses utility, becomes scarce, then it acquires value; but this is an increase of poverty.

A number of writers are now trying to prove that labor is the source of all wealth, while others are trying to prove the contrary. As many of these writers confound wealth with value, and as they pay no attention to the difference between the value of extension and the value of intension, it is easy to see how inconclusive must be this controversy.

In order to make clear in one of its phases the relationships between quantity, wealth and value, I ask attention to the accompanying diagram.

Let us assume that a quantity of water varies, as the line AG, from drought to deluge. At A there is absolute drought; from E to F satiety; from F to G there is excess and at G deluge. Let EC represent the quantity that is just sufficient to supply the wants of the community. When the quantity diminishes to LM, and labour is required to make good the deficiency, the water acquires a value, represented by LP. As the quantity falls to NO, more labour is required, therefore the value increases rapidly to NQ, and towards A the point of absolute drought, the value advances towards infinity AH; for, all that a man hath will he give for his life.

From E to F the variation is so slight as to make no appreciable difference in utility or value.

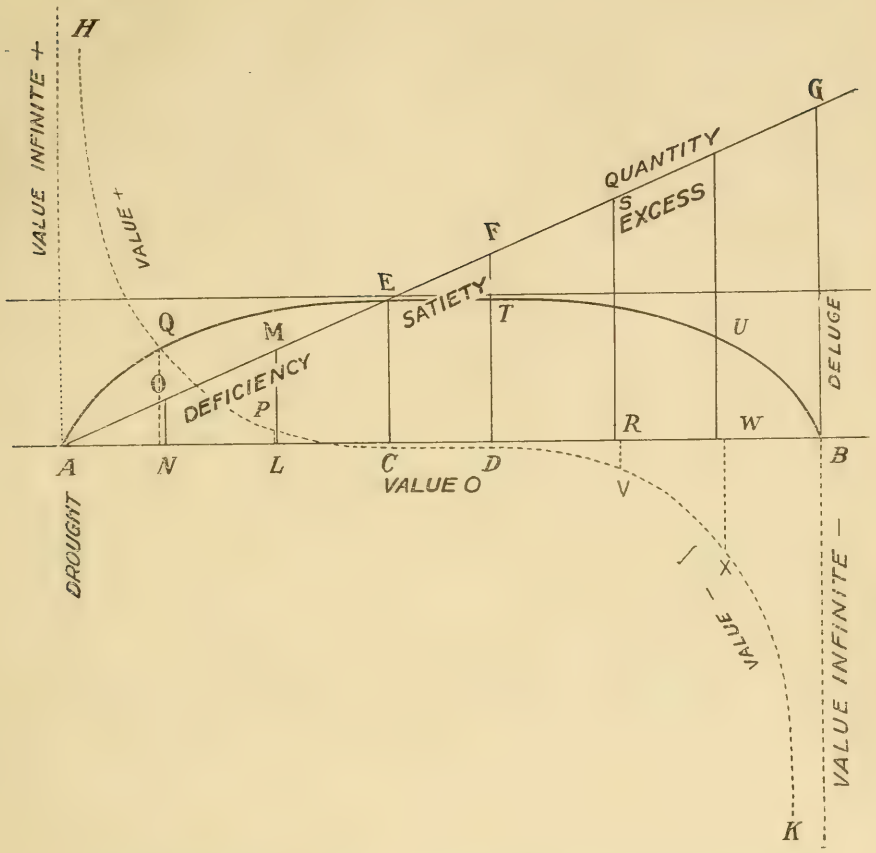
From F as the quantity becomes increasingly excessive towards G, more and more effort will be demanded in the way of drainage and otherwise, not to get a supply of a beneficent agent, but to get rid of a destructive agent. Therefore, there will come a negative value, increasing as the curve DVXK, varying negatively from zero to infinity. (Jevens p. 137.)

The variation of value will, therefore, be represented by the curve HQCXK, varying from infinity + to zero, and then to infinity —.

Let us now trace out the variation of wealth. At the point A, where there is absolute dearth, it is quite evident there is no wealth. Also at the point B, where the deluge is wholly destructive, there is no wealth. From the point A to E there is increase of wealth, and from T to B there is diminution.

To trace the variation of wealth from the point A to E it is necessary to observe the variation of utility as a quantity increases from dearth to satiety. Jevons says, "A quart of water per day has the high utility of saving a person from dying in the most distressing manner. Several gallons may possess much utility for such purposes as cooking and washing; but after an adequate supply is secured for these uses, any additional quantity is a matter of comparative indifference." . . . "It is clear then that utility is not proportional to commodity." (Jevens p. 47.)

It is quite evident, therefore, that any increment from A to O has greater utility than the increment from M to E. The curve of wealth therefore will diverge upward from AO and will converge to ME and will therefore form a curve in the direction AQE. In a similar manner the



curve after the point of satiety is passed will be in the direction TU B The variation of wealth, therefore, will be represented by the curve AQEUB.

From this analysis we find that wealth and value, instead of varying concurrently and being identical, vary inversely, wealth being at a maximum when value is at zero and wealth being at zero when value is at a maximum. A complete examination would require more diagrams than I can present on this occasion.

In tracing the growth of any city we find some of the most remarkable contrasts between the two values, the value of "extension" and the value of "intension."

Some years ago a writer described in the most graphic manner the constant stream of supplies flowing into a large commercial centre for the

maintenance of the people therein. He represented the cattle supplied to the city of London in a year as a vast procession ten abreast extending to a length of seventy-two miles. The sheep would form a similar procession winding its way one hundred and twenty miles. The calves and hogs would form a third pageant of twenty miles, while the bread would cover an acre to the height of a quarter of a mile. This estimate was made at the time when the population was two and a half millions.

The aggregate value of these vast supplies would amount to hundreds of millions of dollars every year, a value of extension.

But when we examine the value of the land we find the widest possible contrast. Do we ever hear of vast streams of land conveyed from the places where it is abundant and cheap to the places where it is scarce and dear? Do the market reports tell of the abundant production of town lots raised on the farm or produced in the factory, to be shipped to the city, to replace those that are consumed or worn out? Do land-speculators increase the utility of the land and thus increase its value, as mechanics turn the crude valueless ore into the locomotive worth its thousands?

These queries at once call attention to the wide contrast between the value of labour products and the value of the land. This difference is so far reaching, and a proper knowledge of these differences is so important to the success of our civilization, that it cannot be too carefully investigated.

Whence come the vast streams of commodities that supply the wants of the city? Let industry stay its hand, let it cease to sow in the spring, let it refuse to attend the mines, the railroads, the factories, the preparation of the food, clothing and a thousand other necessities, and at once we would learn the origin of these values. We can see the men who do the work, and we can tabulate their names and their time.

But to what name shall we credit the value of the lots in the centre of the large city? A certain number of men are necessary every year to produce the buildings and the crops, but how many men are assigned to the production of land-values? Which set of men can say, "We have toiled at these lots till we have changed their value from nothing till now they are worth five millions per acre?" How is it that the land has no value beyond the margin of settlement, a small value in rural districts, more value in the village, greater value still in the towns and then rising till in the largest cities, it will sell at a price of millions of dollars per acre?

Individuals, by spinning, weaving and fashioning can add value to the raw material; but no individual can make land-value. The value of the locomotive depends largely on the amount of utility that labour has added thereto. Half finished it is worth so much, more finished it is worth still more. But the value of the land depends on the presence of the community, the greater the concentration of population the greater is the value of the land.

The locomotive value is an "individual" value, due to the toil that individuals have bestowed thereon; but the value of the land is a "community" value, depending on the presence and aggregation of population.

As the city grows the houses and goods are multiplied. The increasing value of these is a value of "extension" indicating their increased abundance. But as population increases on a given area, the land is divided and subdivided, till where the first settler found a thousand acres available, there crowd a thousand people on a single acre. The increased value of the land does not indicate any increase in the acreage, but the increased value of each acre. The more the crowd becomes congested and the more the people must economize in land, the dearer it becomes. This is a value of "intension."

The boy who cleans my boots this morning must repeat the operation to-morrow morning. The value will not last more than twenty-four hours. The fruit that comes to the market this morning, must be sold before the night. The paper of to-day, will be valueless on the morrow, and the meals must be repeated three times every day in the year. The value that labour produces declines with marvellous rapidity. The city must have its constant stream of supplies or there will soon be dearth. When a snow blockade cuts off the supply of milk, we see then how close is gaunt starvation. Labour-produced values fade as does the leaf; they are marked with transition and death.

But with the value of the land in the growing city it is utterly different. The land of New York city, which sold in 1626 for $24 is worth to-day more than a hundred million times that figure. This value not merely remains year after year, but with every addition to the population it increases. The value of the goods in the store will have disappeared in a few days; but the value of the land beneath the store may continue till the crack of doom. Fashions change, the moth doth corrupt and thieves may break through and steal, fires may consume; but neither the gnawing tooth of time, nor the corroding of rust can diminish the value of the land. For more than a century the civic population on this continent has doubled every ten years and the value has advanced to such a degree that the acre

in New York which could at one time have been bought for a week's work, would now command the wages of twenty thousand years, three times the period since Adam, according to the common chronology.

To maintain the supply of food, clothing, housing, etc., men must toil generation after generation. By no possible combination of industry, thrift, co-operation, organization, or improved processes can man produce so much in one generation that the next will be relieved from all toil. Nature's decree is inexorable. Toil or die. This is true of the values that come with individual energy. But with the value of the land it is far otherwise. This value stays with the crowd like a shadow. So long as we have the assembly of the crowd, there will abide the value of the land.

During the last century the world has made a leap forward in the way of marvellous inventions to a degree never paralleled in any other period of history. The cost of transportation has been reduced in some cases a hundred fold, and the same may be said of the production of many of the fabrics. But no hint has ever been made of any method whereby we can reduce the value of the centre lots in the city. In fact these marvellous inventions have tended the other way.

Here are enumerated several important distinctions between the two values. These differences are so great that what we affirm of the one value we must deny of the other. The first value is the result of individual effort, the other is not; the first indicates greater wealth in goods, the second does not, it indicates greater poverty in land; the first value is transitory, the second is not transitory, but perennial, abiding for ever; the one demands the toil of individuals age after age, the other does not; but depends on the presence of the crowd; the first can be reduced by ingenious inventions, the second cannot.

As there are two distinct values, the one indicating greater wealth in goods, and the other indicating greater scarcity in land, mines, etc., so there must necessarily be two kinds of trade, so long as individuals are allowed to claim the values of these gifts of nature.

When the farmer meets the mechanic, each with the product of his industry so that they may exchange, the result of this trade is mutually beneficial. It is reciprocity of service and reciprocity of riches. It is on this kind of trade depends the possibility of the development and progress of civilization.

When we look at the manner in which society automatically divides itself into different occupations, each rendering its service for the benefit

of the whole, we find that their products are complementary each to the other. For the service of humanity, we must have so many farmers, so many mechanics, so many doctors and so on, each necessary for all the rest and all the rest necessary for the support of each. When the farmers have raised their crops they have done their share of the service to pay for the services of all the rest. The same is true of the mechanics and of all the other occupations. In this relationship there is not necessarily any debt. Service pays for service.

But in the relationship between the industrial classes and the collectors of land value, there necessarily arises debt, which continues to grow larger and larger age after age. Where the first settlers in the city had to pay a dollar an acre yearly for the occupation of the land, their successors had to pay hundreds or thousands yearly, and the successors of these will find that they will have to multiply that payment still more. The farmer charges for the crop of the year, and his charge ceases; but the man who charged a dollar yearly a century ago for the use of an acre, was empowered by law to leave to his successors the power to charge for that acre year after year continuously. By allowing individuals to charge their fellows for the occupation of the land, we establish a relationship which places one part of society under an obligation that grows year after year, thus making a debt which increases continually, which is everlasting and which under present conditions is irredeemable.

How then shall we define wealth? To identify it with value is a fatal mistake, for while the increase of one kind of value is concurrent with an increase of wealth, the increase of the other kind of value indicates an increase of poverty. It is also a mistake to confine the term "wealth" to the products of industry. For the proper investigation of the distribution of wealth, we must carefully distinguish the gifts of nature, the "Natural Wealth," from the products of industry, 'Labor produced Wealth" (MacVane p. 39). For the same purpose we must also carefully distinguish the values which are due to industry from the values which are caused by the presence of the population, and which attach themselves to the land, the forest, the water-powers, the mines, and the franchises. Then, again, we must not confound wealth with individual riches. The disappearance of the forests has made many a lumberman and mine owner rich, because the world has grown poorer. The wealth won by the land-speculator or the stock gambler can be gained only by the impoverishment of the producer. Wealth and the distribution of wealth are two different things, and more than one treatise is a jumble of confusion, because the author has confounded wealth with individual riches. It is a terrible mistake to define wealth as the power to appropriate, as some writers have done, and to teach that slaves are wealth, as others have done, is to confound wealth with spoliation.

SPACE AND ITS DIMENSIONS

A CRITICAL STUDY.

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CHAPTER I.

THE NATURE OF SPACE.

1. SPACE IS SUBJECTIVE.

FOR the naïve consciousness space presents apart from its infinite extension and divisibility scarcely a problem at all. For him who from lack of time or inclination avoids philosophical analysis, space is that in which we are and in which everything is, and with that the naïve mind stops. But the philosopher, i.e., the man who *thinks* and who does not stop thinking at the conventional stopping places*) sees a great number of problems which puzzle him and which have puzzled thinkers of all times. The more general of these problems may according to the branches of human study which are involved in them be classified under three headings:

1. There is first a chiefly *metaphysical* and *theory of knowledge* problem about the very essence of space. It is concerned with the question of the *subjective* or *objective*, *relative* or *absolute*, *qualitative* or *quantitative nature* of space.

2. There is secondly a problem belonging to *theory of knowledge* and *psychology* alike: whether the space of experience is simple or complex. Whether we have to take it as an ultimate fact which can qualitatively be no further analyzed or whether it can be derived from something simpler.

3. There is finally a third problem with which *psychology* and *physiology* are concerned. It has to do with the conditions and the

*According to this definition one man may be a "philosopher" even if he is not able to spell the word philosophy and another may be a "non"-philosopher though he has "studied philosophy" for many years.

laws according to which we order our perceptions definitely and unambiguously in space.

The first problem in so far as it refers to the question of the objectivity or subjectivity of space must since Kant's Critiques be regarded as settled. We can not *know* anything of an objective space. Though there are no limits to our beliefs, (if only we avoid contradiction) there is not much sense in saying we believe there exists an objective space, for what is existence if it is not a certain complex of space relations? Just here it may be worth while to examine briefly our idea of existence. Generally we have two ways of speaking of existence or reality. That which is real or exists is either that which takes part in consciousness or that which has certain space and time relations. If existence or reality means the former, then everything which is in my consciousness must be real, even the products of my imagination, for they exist as constituent parts of my consciousness. In this case everything is real except the products of human lie. If on the other hand, existence or reality means a certain complex of space (and time) relations (involving especially continuity) reality and existence are confined to certain facts and are denied to others. In this sense people say, for instance, that direct impressions are real, and that the products of imagination, the images of memory, are unreal. The objection will be raised that there might be a third meaning to the term existence. If so, please let us know what it is; we claim that all definitions of existence if they are not a vicious circle, come to one of the above two or a combination of them. That is especially so with the reality or existence of the "things" or external objects; for "things" consist of a complication of direct impressions and memory images or imaginations. Naïve realism and often the physical sciences regard the reality of the things, the objects, as of a higher order than that of the states of consciousness, which, it is alleged, might be illusory. They attribute, so to say, to the object, that is to the thing behind the phenomenon, a reality more "real" than the reality of the directly given facts. Even in modern times there is a school of philosophers which, in spite of the convincing arguments of Kant, Wundt, Mach, and others on this subject, still insist on seeking a real but hidden reality (Realität) behind the deceptive given reality (Wirklichkeit). I must beg to be excused for stating the fundamental proposition of these philosophers in the above obviously illogical terms. It cannot be done otherwise, except in taking refuge in words of different languages, which originally stood for the same conception but for which you then stipulate an imaginary difference in meaning. Thus, for instance, we have in Germany the new "Realitäts versus Wirklichkeitsphilosophie," though it takes a good amount of juggling and tight-rope walking, on the stage of philosophy, to

establish the difference between "Realität" and "Wirklichkeit." If people say my imagination of an angel or a dragon has no reality, the dragon does not exist, but the love for my country is real, exists, they employ, though without being fully aware of it, two different conceptions of reality or existence. Philosophers and theologians of all ages have made frantic efforts to prove the existence of God, because they failed to see that to attribute existence to God means to lower the Divine Being to the level of His creatures. If existence is taken in the first of the above stated meanings, God may exist as a phantasm, a product of our imagination. If on the other hand we apply the second meaning, God is nothing but an object in space or space itself (Malbranche). In either sense it is blasphemy to attribute existence to the Divine Being. The Divine Being, we believe, is that through which everything has "existence," consequently existence cannot be attributed to Himself. Existence is too low a term to be predicated of the Divine Being, except we attribute it only to Him and to nothing else (Spinoza). The playing with the ambiguous words, reality and existence, is to a large extent responsible for the discord of the philosophical systems which has brought metaphysics into such discredit. Existence and reality are spoken of as if they meant something about which everybody was perfectly clear and which did not need definition; but only those expressions which designate absolutely simple elements which cannot be further analyzed, need no definition, or if they needed it, could not have it. Such conceptions of ultimate elements are never ambiguous. Consequently, he who uses the term existence, or reality, must either show that these words designate simple unanalyzable facts, or he must give an unambiguous definition. But neither of these has ever been satisfactorily done. But more than that, I claim that the terms existence and reality have only become so prominent through human lying. *The facts can never be unreal or non-existent.* Nothing is unreal or non-existent except the products of wilful human negation, consequently the distinction of real and unreal, existing and not existing would not be necessary if men in their statements to themselves and others would keep to the facts. Philosophy has for thousands of years attacked the problem from the wrong end. It has always been hunting for a greater "more real" reality behind the given one, of which it was falsely alleged that it was deceiving. The given facts never deceive, but our untruthful interpretation of facts does so. Philosophy should not ask: Is there anything "real" and what is it? But it should inquire: Is there anything "unreal," and what is it? Truth and untruth are subjective, there is no such thing as an objective untruth, an error of nature or a contradiction of facts. All error, illusion and deception lie not in the facts but in the interpretation, consequently

there is no use in hunting for an objective reality. The most common feature of all reality is that of being subjective and consequently the greatest "objectivity" in thinking consists in keeping absolutely to the subjective truth.

This all applies to space. Space as we know it is real. It is like all realities, a part of our consciousness. Everybody must admit that he cannot know any objective space if objective means outside of consciousness. Prof. Külpe, in his magnificently sketched exposition of the philosophy of Kant* while admitting this, asserts that it is nevertheless by no means sure that space is objectively not as we have it in consciousness. He says it is quite possible that space is objectively exactly as we experience it.

But I might ask here what can be meant by this "is." If we speak of any object and say it "is" so, for instance it is green, hard, and so and so large, etc., that means we perceive these properties with our senses, i.e., as parts of our consciousness. Any quality which we attribute to a thing must be either directly perceivable or at least be thought as perceivable. When we say that a certain chemical element has such and such specific gravity, specific gravity means nothing but a certain complex of inter-related states of consciousness. When we affirm that a substance has so and so many molecules, atoms, ions, or electrons, to the cubic millimeter, we at least assume that we could perceive those particles if we could change the condition of our perception in a certain way. Of course as long as we cannot do that, all statements about molecules, atoms, ions, and electrons, are matters of belief, not of knowledge. They neither possess the assertive certainty of directly given facts nor the apodictic certainty of possible relations (mathematical axioms and their derivatives). To speak of properties of space beyond these which are possible in consciousness is utterly self-contradictory. All Külpe can say if he does not want to fall back into the errors of naïve realism which Kant has so clearly pointed out (though he is himself guilty of some relapses) would be, that we could believe something might correspond to the space of our subjective intuition, but we could never know it, never predicate anything of it. It could not be space at all, for that would endow it with properties of states of consciousness, and last not least, correctly speaking, we could not say that it was "something." For the property of having part in consciousness is common to all facts. To speak of purely objective facts would involve, therefore, a contradiction in terms. It is all right to call a certain complex of facts i.e. of phenomena a "thing," but to speak of a thing hidden behind the perceived phenomena and then even to pretend

* Aus Natur und Geisteswelt, Emanuel Kant, Darstellung und Wurdigung.

that this unperceived thing is like those phenomena has no sense at all; it means the same as saying "a thing is what it is not." What meaning, for instance, could it have to say a surface was green apart from any consciousness? The so called primary qualities are just as subjective as the secondary. There is, as Wundt has shown, no need for duplicating the world by dividing everything into a thing in itself, and a presentation of the thing.

2. SPACE IS RELATIVE.

If you ask less educated people how big the moon appears to them, you will receive all kinds of answers. One will say, it looks as large as a ten cent piece, another as large as a plate, another as large as a carriage wheel, etc. These people do not realize that their decisions mean nothing; they all are equally right and equally wrong, for you can hold a dime, just as well as a plate or a wagon wheel in such a distance that it just covers the size of the disk of the moon. The only way of determining the apparent size of an object is by stating in degrees the size of its visual angle. That we are usually able to state to some extent correctly in terms of feet and yards the sizes of terrestrial objects is due to the fact that we tacitly refer to a certain more or less definite normal distance. Whenever we measure with a yard stick, or with feet and inches, or with a chain, we always have a standard which itself is either not measured, or which is measured by a smaller unmeasured standard. Thus our statements about the magnitude of things are relative, they really never give an absolute size, but they always say a thing is so and so many times larger than another one. The only occasion where we apparently measure without a standard is, in case of continuous magnitudes when we express the quantity in terms of degrees, i.e., fractions of a great circle in the vision-field; and in case of aggregations of discrete things, when we count the objects. But in counting, the unity is arbitrary and the expression in degrees is the archetype of relative measurement, it does not say anything about absolute magnitudes. Nowhere in the world have we a possibility of absolute measurement; all quantities are relative, and if we regard space as a quantity, which we are entitled, though not compelled to do, this law of relativity applies to space also. All magnitudes in space and all movements too are relative. We have no right to say a thing is absolutely at rest or in motion. When we say that a thing has moved from one point of space to another point, that means that the space relations, distances, etc., between that thing and all other things have been changed in a certain way. Whether the thing itself has moved or whether all other things have been correspondingly dislocated in the opposite direction, cannot possibly be said. In fact, there

is no such thing as a logical distinction between the motion of one thing say to the north and the motion of the whole universe with the exception of that one thing, in the opposite direction. That we usually attribute the motion to the smaller part, thinking the remainder of the universe at rest, as for instance in case of the Copernican System versus the Ptolemaic, is strictly speaking only a matter of economy of thought. Whether we say the earth turns around its axis or the whole extratelluric universe revolves round the earth, amounts to the same thing. The facts say the one as much as the other, they state nothing more than that space relations between the earth and the rest of the universe are continuously changing in a certain way.

The significance of the relativity of space magnitudes may be illustrated by a consideration, the first mention of which, if I am not mistaken, goes back to Condillac. Suppose the Lord should put us all into a deep sleep, and while we slept should reduce the spacial extension of the whole universe, or at least that part which is accessible to our senses and scientific instruments, to a hundred millionth part of its present extension without making the least change in the proportion of the objects and their parts. The earth would then have scarcely the size of a bowling ball, and we men would then be much smaller than the tiniest infusoria and bacteria. Now when awakened next morning would we not be astonished to find everything so small? Not at all. We would not even notice a change, for all our standards would be reduced too. Men would still be five or six feet tall, and the Cathedral of Ulm, and the Washington Monument would still be about a hundred and sixty meters high. The Paris normal meter would deviate for the same fraction as before from the ten millionth part of a quadrant of the earth's meridian. It is even not necessary that the Lord should go through the trouble of putting us into a deep sleep; he can accomplish the whole procedure before our eyes, and we could never notice anything. Since we could not possibly notice it if He did it, we have no right to say He does not do it. In fact the absolute size of the universe known to us, and everything in it may be subject to enormous fluctuations which we have no means of noticing or ascertaining. Against the above argument the objection might be raised that it would be impossible to change the absolute magnitudes without damaging the proportions in time and gravity, but it will easily be seen that time does not enter into this question at all. If the orbits of the planets and the amplitudes of the waves of light and electricity are reduced in magnitude, the time magnitudes could remain the same as now, even absolutely, if that means anything. A little more intricate becomes the problem with regard to weight or gravity. Would gravity remain the same on a celestial body if the volume of that

body were increased or decreased by the same number? It is true that if the earth underwent a ten-fold linear enlargement, its volume and consequently its weight, if matter filled space in the same way it does now, would be multiplied by one thousand. But the objects at its surface would be also at a ten times greater distance from the centre; consequently their gravity would have to be multiplied by one thousand on account of their own increase in bulk, and divided by one hundred on account of their increased distance. That would mean gravity would be as everything else, ten times greater—i. e., a stone would fall through ten times greater space in the same time, which leaves everything as before the increase. Let us take the example of a living organism. First let me ask the question: If the present magnitudes of the earth are preserved, could our animals exist if they were constructed on a much enlarged scale? Could, for instance, giant men twenty times as tall, giant elephants twenty times as high as the present ones exist? We must answer no, for when enlarging the linear magnitudes of the body the muscle power which is proportional to the square section of the muscle will increase with the square of the linear magnitude, but the volume and consequently the weight will increase with the cube. Thus the twenty times enlarged man or elephant would indeed be four hundred times as strong; but he would be eight thousand times as heavy, and consequently could not stand on his own feet. He would collapse into a heap. That is indeed the reason why there is for every shape of an animal on this earth an upper limit in size above which bodily increase will be of no advantage, and it is also the reason why nature had to give up the further development of the flying birds. Nature has used four different principles to keep a living organism suspended in the midst of a fluid medium.

1. The principle of surface adhesion. If the two forces of gravity and surface attraction act antagonistically on a body of a given shape, the result will be the more in favour of the surface attraction the smaller the body is. That is the reason why very minute particles of telluric or cosmic dust remain suspended in the atmosphere. Gravity is not able to overcome the adhesion between the surface of the particle and the air. This is valid not only for inorganic dust but also for organisms, and the more so the smaller they are. If there are cosmic or telluric ultramicroscopic germs of life as Svante Arrhenius assumes, they cannot fall on the surface of the earth, they must remain suspended either on account of the adhesion between their surface and the air, or, if there is no such adhesion, on account of the cohesion of the particles of air, which will resist the passage of particles of a heavier substance if the latter are below a certain weight.

2. The second principle is that of floating on account of equal specific gravity with the medium. This principle, which nature employs chiefly for animals in the water, man has adopted in the balloon.

3. The third method is the employment of a very rapid movement of a character not perfectly explained yet. We see this principle in the flying apparatus of the insect. It is obviously applicable only in case of comparatively small creatures.

4. The fourth principle is that applied in the birds, bats, and other flying animals. The suspension in the air is obtained partly by downward pressure, and partly by the kite-like gliding movement of the wings, the surface of the latter being immensely enlarged by the feather system.

The above mentioned relations between surface and gravity, determine the limit of size for flying creatures on the surface of this earth. Nature has not succeeded in producing flying birds above a certain weight. The extinct Moa were very large birds, but they could not fly, nor can the cassowary and ostrich. They are too heavy. Nature, using the above mentioned principles, could not produce wings which would carry a larger body and a larger brain, and since the latter, i. e., the increase of brain was indispensable to further development, it had to give up flying as the chief way of locomotion for its highest creatures, and was compelled to branch off from a lower order again, laying all stress on the evolution of brains. Thus the mammals arose which are bound to the earth. And to the brain development of the highest species of mammals i. e., man, it is left to find another (fifth) method to suspend a body in mid-air, a method which will not fail in the case of greater weights. For with the application of the fish (balloon) and the bird method, one will scarcely get much further than Nature.

Let us see now what would happen if that twenty times enlarged animal and the surface of the earth would also be removed to twenty times greater distance from the centre. The weight of the animal which was twenty times too great for its muscle power would have to be now multiplied by 20^3 on account of the increased mass of the earth, and divided by 20^2 on account of its greater distance from the centre, thus it would have $\frac{8000}{400}$ times, i. e.—twenty times the weight of the original animal, but as it is twenty times as strong the two influences just cancel one another.

3. SPACE HAS IN FIRST LINE A QUALITATIVE CHARACTER.

When experimental psychology saw the light of the world as a new science, there happened, what in fairy tales so often takes place at the birth

of princes and heroes. An unkind fairy threw an undesirable present into its cradle, namely, the problem, or better the alleged problem, of the measurability of psychical magnitudes. Everybody was accustomed, for reasons which I have never been able to see, to exclude extension from the territory of the psychical and assign to the latter only the qualitative and the intensive. The opponents of experimental psychology took refuge with Kant to whom of course the modern problems of the quantitative relations between the physical and the psychical were as foreign as smokeless powder was to the medieval knights, but who had said somewhere that psychology—by which he understood something totally different from that which we mean when we use the term—could never become an exact science. They forgot that the same Kant in a far more prominent passage of his critique laid down as one of the most important foundations of experience, indeed as an anticipation of every perception (rather loosely connected with his categories of quality) the axiom: Every phenomenon has an intensive magnitude, a degree. What is a degree other than an observable and measurable magnitude?

The adversaries of the new science raised the question: can psychical magnitudes be measured? At the base of this way of putting the question lies the taking for granted of the fundamental distinction of the physical and the psychical. The physical according to the popular view comprises extensive as well as intensive magnitudes. The psychical had only intensive magnitudes. Now the question would be, either: 1.—Can intensive psychical magnitudes be measured? or 2.—Can intensive magnitudes be measured at all? If the former version is preferred, the opponents of experimental psychology must either establish a difference between physical and psychical intensities, or they must agree that their blow hits physics as well as psychology. With regard to this we might ask —What is intensity physically? Is for instance light-intensity physical or psychical? Has the physicist any right at all to speak of intensity? If he makes up his world of little particles, atoms, ions, or electrons which move in space, if he does not take refuge in dynamical suppositions which at once admit the miraculous or inexplicable, he will have to define his intensity in terms of extensive magnitudes as velocity, acceleration, amplitude, etc. On the other hand if the physicist or astronomer makes photometrical investigations, is his procedure and the criterion of his judgment essentially different from that of the psychologist when investigating light intensities? Do they not both rely in the last instance on a comparison of psychical facts, states of consciousness? Does not every photometrical experiment rest on the subjective decision, which of two perceptions is the brighter? And does not always a least observable difference remain as an irreducible residuum? Is not the classification of

stars, once according to apparent magnitudes and another time according to physical intensities, a striking example of a psychological experiment according to the method of mean or multiple gradations, though the observation was made two thousand years ago in the time of Hipparchus, while we have only lately succeeded in measuring the physical stimulus? But, it might be said, just the fact that the measurement of the physical stimulus has another result than that of the psychical impression proves that there is a difference between physical and psychical intensities. But what is the physical intensity here? It is something not intensive. It is either (1) the angular width of an obscuring sector (a rotating disc) (2) or the turning angle of a Nicol prism, (3) or the thickness of an absorbing medium, (4) or a number indicating how many candles would give the same intensity, (5) or some other device to express intensity by some special or numerical equivalent. Thus we must come to the conclusion that what is called physical or objective intensity is either something not different from the subjective or psychical intensity or else it is not intensity at all.

Having thus seen that a valid distinction between physical and psychical intensities cannot be drawn, our problem must necessarily read: can intensive magnitudes be measured? And this question must be unconditionally answered in the affirmative. Science has for centuries succeeded in measuring intensive magnitudes, though we cannot admit that they were physical and objective. We measure pressure, electricity, heat, light, gravity, and other attracting and repulsing forces. But in every case we find on closer analysis, first, that the quantities measured are in the last instance psychical (intensities of light, pressure, effort, etc). Secondly, that all our measurement rests finally on the decision whether, (a) two intensive magnitudes are equal or not, or (b) whether or not the difference between the two intensive magnitudes is equal or not to the difference between two other intensive magnitudes.

This is even so in the case of extensive i.e., spacial measurement. In fact if on the basis of the theoretical attainments of modern mathematics, and the experimental attainments of modern psychology, the question of the measurement of intensive or psych cal magnitudes is raised again, the tables will be turned and the question will then read: do we ever measure anything but intensive and psychical magnitudes? And further is extension, space, in first line magnitude, quantity? Let us test in the following, this radical reversal of the problem.

First, there is no reason why the spacial properties of sensation should be regarded as less psychical and more physical than their intensity. No one who has studied Kant and has kept in touch with the results of

modern psychology can regard the spacial properties and relations as objective unless he means by objective the product of some abstraction from the subjective, or as Wundt views it, the one of the two abstractive aspects of the "presentation-object" which latter is at the same time subjective and objective.

All doctrines which duplicate the given facts by setting them once as external objects and again as presentations in the mind, must as far as knowledge i.e., certainty is concerned, be regarded as utterly untenable. I cannot understand how a modern philosopher or psychologist can make a statement such as that found in Stout's Analytical Psychology, which reads: "My idea of a triangle is not triangular." He adds as an explanation, "for it is not made up of lines and angles." Certainly my idea of a triangle is made up of lines and angles, and certainly it is triangular, for my idea of a triangle is all I have of a triangle, it *is* the triangle. If I speak of an extra triangle existing independently of me, that triangle can be nothing else than an idea or a complex of ideas. If Stout had at least said, the thing in itself which produces the triangle (my idea) may perhaps not be triangular, one might excuse it, for there have been greater men who spoke of the thing in itself and proved on the next page that one could not speak of the thing in itself. My idea of the triangle is the only triangle I know, and it is certainly triangular and made up of angles and straight lines. Thus it is absolutely senseless to state that our ideas of space are themselves not spacial* and if you ask those who make such statements what they mean by "our ideas of space" you will find that they are either unable to say what they mean, or their ideas of space reveal themselves in last instance as some molecular processes in the brain, which, of course, are spacial and subjective. For we can have no knowledge of the cerebral processes corresponding to our own states of consciousness, but connect consciousness and brain processes only in a course of inferences on the foundation of analogy, and the cerebral processes which I may observe in a dissected body or corpse, are again nothing but *my* states of consciousness. Thus we see that extension or space is not more objective, nor less subjective than the intensity of sensation. With regard to the application of the conception of magnitude to space, the advantage is just as much or even more on the side of intensity, as we shall try to show presently.

At the basis of the statement that sensation as an intensive magnitude is not accessible to exact measurement lie two tacitly made assumptions which nevertheless are absolutely unjustified and groundless, namely, first, — that magnitude (and consequently measur-

* Elsenhan's Psychology.

ing) is an ultimate conception not further analyzable, and secondly,—that there are other magnitudes than intensities. With regard to the first assumption we might ask,—could there be a single magnitude alone? Obviously not, for only by comparison, by relation to others, does something become a magnitude. Comparison is by no means a simple process. The act of comparison always presupposes that of distinction. By distinction is not meant the quantitative ascertaining or determination of a difference,—for that would be comparison—but the experience: this is not that, it is another. Two simple or complex states of consciousness can only be compared, if there has been distinction first. If two states of consciousness would show no difference at all, they would be identical, i. e. —they would not be two states of consciousness but only one. Distinction refers rather to the *quality*, (as with simultaneously perceived tones or noises, and also with complications of impressions of different senses) or to *space*, (as for instance in the distinction of simultaneous but otherwise perfectly equal impressions i.e., so called numerical difference) or finally to *quality and space* at the same time (as in the distinction of colours). Intensities we can only distinguish if they are separated in space or time, or are qualitatively different, and the distinction in time must in the last instance also depend on space. A purely temporal series of different intensities is only possible if the reproduced idea, (memory image) of the preceding impression is either qualitatively different from the present one, or is represented (in the memory image) as spacially beside the latter. If one single sensation would fill the whole consciousness, we would not be able to perceive a change in its intensity, for the distinction would presuppose that the two intensities, (the one as a memory image) would be at one time *together* in consciousness. Grassman* thinks that the conception of the continuous change of an element could only apply to extensive magnitudes. We could not agree to that, for a continuous change can just as well be observed in intensive as in extensive magnitudes, but in both only by virtue of relations to other impressions. If the mind was filled with one intensive magnitude, and had nothing for comparison, neither a continuous nor any other change of the magnitude could ever be noticed.

Comparison refers to the degree of difference. The fundamental judgment here reads: this is greater, more, or smaller, less than that, or this is equal to that (in quantity only) though it must be different in space relation, etc. Thus comparison concerns the degree of magnitude or in case of qualitative difference the degree of similarity. Now we claim that whilst distinction always refers to qualitative or space differences, comparison, which pre-supposes distinction is *always a matter of intensity*,

*Die Lineare Ausdehnungslehre, page 28. Edited by Friedr Engel.

even if it concerns extensive magnitudes. If we perceive a line or distance as greater than another we pronounce this judgment on the basis of the intensity of specific sensations, which either directly participate in the perception or are reproduced parts of former perceptions. It does not matter what name we give these specific states of consciousness: muscular sensations, feelings of innervation, sensations of movements, kinæsthetic sensations, etc. All our judgments on magnitude rest on such sensations; even in the case of measurement with the finest instruments of precision, where, as it is usually said, the inaccuracy of the human senses is eliminated, we have at every reading in the last instance an appeal to the sense of sight or the sense of touch, no matter how indirectly or by what auxiliary instruments the reading may be secured. Besides this we must not forget that the instruments of precision have all been made by the human hand and with the help of the human eye. I think this is the same fact as Meinong has in view when he says that every measurement is psychical, never purely physical, and that the exactness is nearly altogether in the psychical part.*

There are no purely extensive magnitudes. That which in extension is magnitude is still in the last analysis intensity. The characteristic part in extension is not magnitude; all magnitude presupposes intensity, but extension is not simply a special case of magnitude though it admits of metric (measuring) considerations. Measurement or the determination of magnitudes is not a simple process, but it is composed of distinction and comparison. Number, too, is the product of repeated distinction and comparison. The purely extensive can be distinguished but not measured. It needs the addition of the intensive to make measurement possible.

Comparison presupposes distinction. Distinction is either qualitative or spacial. Qualities can only be regarded as magnitudes in so far as they admit, from some standpoint, of intensive consideration. Consequently measurement though referring to the intensive side, yet presupposes extension. The things to be compared, i. e., the object to be measured and the standard must be separated in space or in time, but even time is only a magnitude when considered in analogy with space. Whenever we speak of the extension of time, we regard this extension in analogy with that of a direction in space. We can measure time only by space, (sun-dial, sand-glass, or clock-face, etc.) and the laws of phoronomy possess certainty only in so far as time can be represented as a spacial magnitude.

Thus we see that the separation hitherto so strongly emphasized of

*Meinong; Ztschr. f. Psychologie und Physiologie d. Sinn. XI. K. 230.

extensive and intensive magnitudes is untenable. All magnitude is intensive and yet it presupposes as a conditio sine qua non the separation in extension, consequently one can not simply say with Grassmann* that the intensive magnitude rises through the production of the equal, the extensive through the production of the different, because the production of the equal presupposes space, as we have seen above. For Grassmann extension is still in first line a magnitude or 'liquid number" through the separation of the elements. This separation of the elements is what we call extension. A pure theory of magnitude independent of extension (i. e. of space) such as so many analytical mathematicians claim to possess is consequently impossible. No matter whether we employ number chiefly as a representative of the quantitative principle (cardinal number) or as a representative of the principle of order (ordinal number), no matter whether the series is continuous or consists of discrete parts, *pure number always contains extension and intensity.*

It is a different question whether we can have a pure theory of extension, a geometry without any reference to magnitude. It is true, magnitude presupposes extension but not vice versa; for the characteristic property of extension (i.e. space) is not quantity but quality, and indeed a quality more different from all other qualities than they are from one another. This quality cannot be expressed otherwise than, "this place in space is not that place." This makes an affirmative answer unquestionable. A theory of extension or space without metrical elements is very well possible. It must abandon every use of intensive considerations. In such a non-metrical geometry we may deal with points, lines, planes, with loci, directions, and systems of directions, but not with distances, angular or other magnitudes. In such a geometry there is no place for size, (magnitude, extension) nor for similarity of figures. For of what we call shape or form in ordinary geometry—shape and form rest partially on relations of magnitude—there is nothing left but "collination." The so called geometry of position, projective geometry, comes close to such a non-metrical geometry, though its promoters are not always consistent in preserving its purely non-metrical character.

We have seen above that space can be considered from two different standpoints, from the qualitative and quantitative point of view. The qualitative and that is the extensive, is the very nature of space, the quantitative, that is measurement by virtue of intensive considerations, is carried into it. For all qualitative continuous manifoldnesses admit of quantitative considerations.

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*Grassmann, Ausdehnungslehre 1 (Engel Ausgabe) Intro. P. 26.

4. SPACE IS CONTINUOUS.

Space and time are the forms in which consciousness arranges the facts given. To such an extent are they intimately related to consciousness that they partake so immediately of that most general property of consciousness, "continuity," that it becomes exceedingly difficult to distinguish between the continuity of consciousness and the continuity of space and time. Perhaps there is nothing to be distinguished. It might be worth while here to cast a brief glance at the problem of continuity in its main issue. Have we a right to ask; What is continuity? I think not. Just as we have no right to ask; What is consciousness? Consciousness is the conditio *sine qua non* for all "asking," for all definition, description and explanation, indeed the condition *sine qua non* for all facts; consequently "consciousness" itself can never be defined or explained. Almost the same could be said for "continuity;" in fact it does not matter whether we say consciousness or the continuity of consciousness. Thus we cannot ask what is continuity. We can only ask "Where do we find continuity?"

Nevertheless there have been many attempts to explain continuity in general and the continuity of life philogenetically, (heredity) and ontogenetically (memory, consciousness) in particular. Poincaré (1) says that in all cases where we observe that two things are equal to a third yet not equal among themselves, we speak of a physical continuity.

$$\begin{aligned} a &= b \\ b &= c \\ \hline & \text{yet a is different from c.} \end{aligned}$$

Wherever we have this contradiction against the law of identity, we have a continuation. This is really the question of the least observable difference or the threshold; but in my opinion it has nothing to do with the deeper problem of continuity. The above argument is based on the assumption that there exists such a thing as an equation, an absolute identity, but there is no such thing in the given fact. Equations are either mathematical fictions or they refer to partial coincidence considered by abstraction. Even that standard equation usually indulged in when discussing the law of identity. "A = A" can be just as well read: "This A is not that A, it is another one." The tendency of the mathematician of the present day to press everything into the form of an equation is due to the present preponderance of the analytical side of mathematics, and

(1) Der Wert Det Wissenshaft, translated by E. H. Weber, p. 51.

this is based on the false idea that Geometry is only a special case of a more general theory of pure quantity. Not "equality" but "dependence" is the most general relation, and consequently the most fundamental formula is not A = B, but A is dependent upon B or A=f (B), where "is" has no other significance than that of a grammatical copula. The mathematical proposition that if two things are equal to a third, they must be equal to one another is of course only valid under the assumption that the three things or quantities do not change but remain the same. But if I say *e. g.*, a certain region (a) of the spectrum is in quality equal to a neighboring region (b), and this region (b) cannot be distinguished from another region (c), though if I compare (a) and (c) I immediately see a difference, we have here in no way an application of the above mathematical axiom. For a colour quality is what it is only in relation to others, and if I compare *a* with *b* it is not really the same *a* as that which I compare with *c*. Here is where the mistake is made. We have, strictly speaking, no right to say a quality is the same because it is attached in some way to what we call the same "thing" That "same thing" is like the "thing" itself, a rather complicated abstraction to which nothing in reality corresponds. We have through thousands of years of training become so accustomed to speak in terms of "things" instead of in terms of elementary given facts (states of consciousness), that we are prone to attribute to these "things" a higher type of reality than to those directly given facts. A striking example of this is given in the discussion of contrast where frantic efforts are made to show why the "same" piece of grey paper looks once reddish and another time greenish according to the background on which it is seen, while the real problem should read: How do we, starting with that difference in the given facts, *i. e.*, in the sensations of colour, intensity, etc., arrive at the idea that we have to do with the "same" piece of "grey" paper.

Furthermore, if Poincaré believes he can reduce the continuum to something which refers to quality and inequality, he is very much mistaken, for in order to make that statement or to have that idea of equality he must have continuity first. How can he compare *a* with *b* if he has not space or time continuity or what includes both, the continuity of consciousness. He has first *a* in his consciousness, and then *b* enters while *a* must *continue* in some way or else he could never compare them. No matter how far they are separated in time and space he must bring them (*i. e.*, the one and the memory image of the other) together at the same time or at the same space and this he can only do by making use of the continuity of space and time or the continuity of consciousness as he finds it at the very outset.

Now let us glance at the other side of the problem: Where do we find continuity? Do we find continuity in nature, i.e., in what we call the external world? Take, for instance the perception of the white surface of a wall. Physically the wall consists of separated particles of lime etc., and the chemist will tell us that these particles consist of many molecules, the molecules of atoms, and the atoms, as we are taught recently, of an infinite number of electrons with comparatively large interstices between, and since even these electrons cannot be mathematical points, the possibility of division is not at an end here. Thus we have in the physical objects separated particles. The light which is reflected from them consists of periodic movements of separated ether elements. All attempts to make the ether a continuous homogeneous solid lead to ridiculous absurdities. The vibrations of the separated ether elements are conveyed by means of separated atoms and molecules of the refracting media of the eye to the retina where they are transformed into a chemical process, very likely in the rods and cones. Each rod and cone is a separate thing for itself and has its separate nerve fibre and this latter consists again of separated molecules, atoms, electrons, etc., etc. Through these separated nerve fibres the stimulation is transmitted to some central station in the brain. Now if we do not want to land at the fallacy of Descartes who gave the soul only a single mathematical point as its seat in the brain (in which point then the whole problem of unity and variety would start anew) we must assume that the central station of the sense of sight, no matter whether it is located in the occipital part of the cortex or anywhere else, must consist again of separated brain cells, and the cells of separated molecules, atoms, electrons, etc., etc. Where in the world does the continuity of the surface come from, which I perceive directly when I look at the wall? This directly perceived continuity has no analogue in the external world, none in the peripheral sense organ, none in the transmitting nerve, none in the central organ, consequently it has no physical analogon at all. *The continuity exists only in my consciousness.* I claim one thing more: *There is no other continuity of which we can know anything except that in consciousness.* Everywhere that we claim to have a continuity objectively, i. e., in the physical world independently of our consciousness, we are mistaken. The continuity is always *in us.* We "inject" it so to speak into that which we call the physical. This continuity of consciousness which is identical with the mathematical continuity in the apodictic realm (space) and with the actual continuity in the territory of the assertive facts (time) is the only continuity we find. There is no other, and as this continuity is the first condition for all analysis and explanation *it is consequently utterly absurd to attempt to explain, describe, or define it.*

CHAPTER II.

THE SIMPLE OR COMPLEX NATURE OF SPACE.

1. The problem which confronts us here is the question whether space is an ultimate element or whether it can be reduced to simpler non-spacial elements. The attempts to reduce space to simpler non-spacial elements can be classed in three groups:

To the first group belong all those theories which try to trace space back to the unity or indivisibility of the soul or some similar general property of the soul or mind. But such views, handed down to us from the days of rational psychology, possess to-day no more value than, for example, the endeavour to deduce the quality green from the general conception of colour, or the existence of God from the idea of a perfect being. In our days theories of this kind do not deserve any serious consideration for the purposes of scientific refutation.

In the second group we have all theories which try to make up space by means of series, movement, and time. But this must be regarded as arguing in a circle for all these conceptions, no matter whether they are intended to mean something unextended or to represent a more general case of extension, presuppose space. This is perfectly self-evident with regard to *movement*, less clear with regard to *time*, and perhaps the least clear with regard to *series*. It has been said that purely temporal series are possible. This must immediately appear objectionable when one realizes that time can only be regarded as extended in so far as it can be represented in analogy with space. It is not true that time presents itself as a one-dimensional extension, or that we experience it as such. The "now" only is given and that does not partake of the nature of extension at all, for it is continually changing. The *past* in so far as it can be an object of knowledge, is *present* as a state of consciousness. It is a part of the "now." In so far as the space perceiving senses come into account the "now" consists partly of ideas with fixed and uncontradicted space localization—what we usually call impressions or perceptions—and of another class of ideas, images of memory and phantasy, which are indeed just as real and as immediately given as the impressions, but which, though showing spacial properties, do not possess that one attribute of the former, uncontradicted space localization. These so-called "reproduced" elements are very often less distinct and intensive than the impressions, but distinctiveness and intensity cannot pass as essential characteristics of the direct impressions. A

memory image may be much more distinct and ntensive than a real impression. Thus my memory image of a certain book is much sharper and more intensive than the real impression I get of the same or another book in the twilight or in indirect vision. Those that hold that direct impressions and memory images are only different in intensity will scarcely be able to face the following question. Suppose you have a series of light sensations, from a very low one, just above the threshold, to a very high one, and further that these sensations differ only in intensity. Now if the memory image is only different in intensity from the sensation, how then can the memory image of a brighter member of the series be distinguished from the direct sensation of one of the members of lower intensity? On the assumption that the characteristic difference between direct impressions and memory images was one of intensity we should expect that for instance, a captain on a lake or ocean steamer would sometimes be uncertain whether a dim light which he sees at the horizon was a real impression or the memory image of a brighter light which he had seen before. This difficulty never arises, we are always perfectly sure about the distinction of direct impressions and memory images, for it is not a matter of intensity or sharpness but one of localization in space. The memory image has inner space relations, i.e., space relations of the parts to one another, but it has no space relations to the direct impressions, it is not definitely localized in the vision field except by indirect association. Wherever I say "Here it is."—"There I see it," it can be answered: "That is not true, there you see something else."

The past and the future consist chiefly of memory images, and imaginations, sometimes called reproduced elements, though "reproduced" can here mean nothing more than a new state of consciousness partly agreeing or identical with a former one. These so-called "reproduced" elements are parts of the present and differ only in the nature of their space-relations from other parts of the present, usually called direct impressions. Thus the past and the future are matters of knowledge (certainty) only in so far as they are parts of the present; all the rest is a matter of belief.

Even if time was, independent of the analogy of space, and independent of the conception of movement into which space and time enter, something extended, there would be still no possibility for purely temporal series. If variation in the spacial relations of position and shape are excluded, a change in a temporal series could only take place in that form that where A is first B is afterwards; thus a successive series of impressions of sight for instance must at least be localized somewhere in space and the impressions must have a spacial magnitude. The ele-

ments of the other senses and even organic sensations are always, though not necessarily very distinctly, spacially localized, and if a sound sometimes cannot be localized in a definite direction it is yet not non-spacial, for it is still vaguely localized either within the body or outside of it in the surrounding space.

Thus we see series in time can never be the elements on which space and its extension is founded, for series are only possible by virtue of time and space relations, and time has an extension, is an extended magnitude only if apprehended in analogy to and measured by space. Consequently if somebody tries to make up space out of components in which time, motion, or series enter, he is arguing in a circle.

In the third group belong those views which try to reduce space to intensity, quality, or the co--operation of intensive and qualitative differences. Here belong the so-called Local Sign Theories in so far as they attempt to explain not only the order in space, but the existence and nature of space itself. The reduction of space to intensity must certainly be a failure since, as we have seen above, purely intensive differences are only possible on the assumption at the same time of extensive separation in space. Besides this, if space were built up of differences of intensity, why are those intensity differences not seen as such? On the other hand it is just as impossible to reduce space to pure qualities. For if the spacial "beside one another" rests on qualitative differences, I cannot see why these qualitative differences should not be perceived as such but as something totally different. Something quite specific must be added to quality or intensity differences in order to make them appear as something else from what they are.

But it might be said that the fusion of qualitative and intensive elements is what creates space, and Wundt, on the basis of his theory of psychical casuality, according to which the principle of equivalence of cause and effect is not valid on the psychical side as it is on the physical, the effect being on the contrary always greater than the cause, has advanced a very ingenious theory of this kind. If this idea that space is the result of co-operation or fusion of qualities and quantities be correct, we should wonder why *this* qualitative and quantitative fusion should only give rise to space in the visual sense. Why do not other fusions of the kind do the same, as for instance those in the sense of hearing? Obviously something must be added to this qualitative-intensive fusion, some extra property which distinguishes this effect from that of other fusions of a qualitative-intensive kind. But agreeing to this argument is tantamount to admitting that this specific extra property just

constitutes the spacial, and the whole reduction to fusion of quality and quantity is in vain. Any kind of "local" colouring, no matter how it is defined, presupposes space. Wundt's theory of the fusion of quantitative and qualitative local signs, which, as we shall see below, renders excellent service towards the solution of the third problem, that about the definite localization in space, necessitates a certain modification in order to make it unimpeachable also with regard to the second problem. For this purpose one needs only to drop the pre-supposition that the specific qualitative differences which constitute the local colouring are originally of a non spacial character. On the contrary one must assume that these quality differences are toto genere different from all other quality differences. In other words we must assume that the difference between all other qualities on the one side, and space on the other side is greater than the differences of the other qualities from one another. In other words that the differences between the other qualities and those qualities which constitute space is a difference of higher order. But then we can just as well say these specific qualities *are* space.

Thus we see, that which is the essential in extension is not magnitude, intensity, but something qualitative. The characteristic quality cannot be otherwise expressed than by propositions like the following ones,— "This is not that," "This place is not that place," "This direction is not that direction," etc. The realm of this continuous manifoldness whose qualities are more different from the qualities of sensations and emotions than these are among themselves is space. Space is simple and directly given and consequently can never be defined or explained (i.e. reduced to something simpler.) All attempts to deduce space from the non-spacial must consequently lead to insolvable contradictions.

The third problem concerns the definite and unambiguous order of spacial perceptions and presentations, and it is here that Wundt's theory of complex local signs offers the best conceivable description of the facts and even does not fail when facing the more intricate problems of vision, the binocular and monocular perception of depth. The order of our spacial perceptions is accomplished through the co-operation of the qualities of extension originally given, with different systems of intensive elements. On the basis of the former we distinguish locations and directions and by means of the latter we estimate magnitudes and distances. Thus spacial *distinction* is a priori, but space *measurement* is a posteriori. Just here we must admit that the expressions a priori, and a posteriori are from the theory of knowledge standpoint just as objectionable as the terms, innate and acquired. If these terms are not to be taken in a purely temporal sense they must be defined with due regard to their relation (dependence

or independence) to experience. But "experience" is next to "reality" the vaguest, the most illegitimate and deceptive conception and even Kant has confused the different meanings it can have. Reality and experience must be either defined in a perfectly arbitrary way or else they can be applied to everything, not even contradictories excluded. Therefore if we want to avoid these questionable though customary means of philosophical argument we may say as follows:—Extension i.e. the characteristic quality of space intuition is absolutely ultimate and unanalyzable. The order of our experience in space is produced under the co-operation of extension and magnitude. This order is complex and capable of differentiation and development. This capability for development does not predicate anything against the apodicticity of the known mathematical propositions. Thus the question answered in the negative by the representatives of the Herbartian school, and answered in the affirmative by Lotze, Wundt, and Ebbinghaus, whether an eye absolutely at rest in a motionless surrounding could have space, must be decided in favour of the affirmative. Such an eye would have no occasion to perceive size and distance, but it would be capable of space distinction just as well as it would be of the distinction bright and dark, red and blue. It could perceive: this point is not that point, this direction is different from that one, this point or direction lies between those other points or directions. These are indeed the last fundamental facts from which the most recent treatments of the foundations of Geometry start.*

The above question is usually only raised with regard to the "two dimensional" extension of the spacial fields of the sense of sight and the sense of touch, for most philosophers and psychologists, even if they adhere with regard to the two dimensional fields of vision and touch to the nativistic hypothesis, think it necessary to admit that the third dimension is only the empirical product of inference. Thus for instance Max Kaufmann† and recently Ebbinghaus‡ have emphasized that the two dimensional or surface nature of visual space is something original and elementary. The latter thinks this original surface-perception is similar to that which we have when we look into a transparent liquid, into the darkness of an un luminated shaft, into a thick fog, towards the sky or into the glare of a big flame. But I do not see what essential distinction there can be between these impressions and other ordinary surfaces unless it is in the difference of intensity, of saturation or colour tone. The flame presents itself as a bright orange yellow, the fog

* David Hilbert, Grundlagen der Geometrie, Festschrift zur Enthuellung des Gauss-Weber-Denkmals in Göttingen 1899.

† Immanente Philosophie pp 10 ff. (3)

‡ Psychologie Vol. II. 440.

as a grey, and the shaft as a black surface, that is if they are homogeneous. If they are not, then you see different distances. The approximately lightless shaft, it is true, is much "blacker" than an ordinary so called black surface on which you still can see the shadows. But if one does not correct that which is actually perceived by that which one claims to "know," it appears perfectly surface-like. I have convinced myself of this once by an experiment made as a kind of a joke on the occasion of one of those illustrated social functions which we have at least once every winter at the University of Toronto. For the benefit of some artists among the guests I had exhibited a number of different intensities of the achromatic series arranged in a plane. The brightest one was a good white paper, then came several greys, then a black paper, then black velvet, and the last was an aperture into an approximately lightless space. This opening was as much different from the black velvet as the latter was from the black paper.* I offered one hundred thousand dollars to the artist who would produce with oil or water colours on canvas or paper, this series in its correct intensity relations. The greater number of the spectators did not understand the problem at all, they found it beneath their dignity to consider the question which could of course only be a "language trick." If they are painters I suppose they are the kind who paint the rising sun so realistically that it could just as well or better represent a plate on a cupboard shelf. But many who found it worth while to examine the case took the dark opening for some kind of better velvet and were greatly startled when on attempting to touch the apparent black surface they found no resistance. Nobody without being aided by the sense of touch could perceive that it was not a surface but an opening into an empty space. If we look into a transparent liquid or into a fog we see either the irregularities, the deviations from homogeneousness (in the case of the fog in the whole mass, in a transparent medium perhaps only at the surfaces which form the interior and posterior boundary), or we see a homogeneous surface. Hering is quite correct in stating that in such cases sufficient indications of certain depths are not entirely lacking, but even if they are lacking completely we see in this surface as in the case of every other surface not a surface in *no* distance but one in an *indefinite* distance.

The theories which claim that two dimensions are given and the third one is gained by means of inference will scarcely be able to face the question: can one perceive a surface without seeing it in some, though perhaps indefinite, distance? Suppose the originally given space of vision be a sur-

* See also my treatise on the æsthetical significance of light and color contrast. Philos. Studien Vol. VII. pp. 362 ff. and also Laws and Conception of Aesthetic. U. of T. Studies, Psychological Series. Vol. I. p 177.

face and nothing else; of course it must of necessity be a plane, for a curved surface would pre-suppose depth perception. Perhaps one could accept also the surface of an infinite sphere. Then all things which we perceive, including our own body, and consequently the mind's standpoint of observation should be *within* that surface. Though we cannot say the ego is definitely located in the body or in the brain, we nevertheless give at any point of time a definite location in space to the standpoint of observation.

In monocular vision we put the standpoint of observation into one point of the axis of the eye and in binocular vision it is a point somewhat behind the middle point of the straight line which combines the centres of the two eyes. Now if the visual space were originally given as a surface in no distance, we, *i. e.*, our standpoint of observation would necessarily be in that surface too, and then arises the question, could we see a surface at all? It must be answered in the negative, for we would only be able to see lines, in other words even the second dimension would already be a product of inference, not something really given. So much is certain, one cannot perceive a plane from a point within that plane. The *conditio sine qua non* for the perception of a surface is to be outside of that surface. Thus the perception of two dimensional space structures silently involves what is usually called the third dimension, but what, as we shall see later on, should better be designated "extension in all possible directions."

As everywhere else, so also in case of the perception of a surface, Wundt's doctrine of the presentation-object, according to which the distinction of subject and object is the outcome of abstraction, is valid. At the moment when I perceive a surface I am the perceived surface. I am not only the perceived surface but I am a great many other things. If now the other things which I am or experience are not within that first surface, then it is clear that I must have immediately more than a two dimensional space. It is claimed that man has in his early childhood no perception of depth, for, so it is argued, the child grasps for the moon as well as for an apple. This proves only that at this age no measuring exploration of the depth has as yet taken place, so that the child, though he puts the moon and the apple in indefinite distances, has not yet learned to apply magnitude to distance. It is perfectly correct that our light and colour sensations are of a surface nature, but the perception of a surface is only possible in fully extended space. A seen surface is only the far limit of a perceived part of space extended in all directions; we might say the basis of a transparent pyramid the apex of which is in the eye. Even our memory images and the products of imagination are not excepted here. Though they have no definite localization in the vision field, they

have yet in a way, extension as well as magnitude, and they are always projected in some, though often, an indefinite distance. The third dimension, if for the time being we may make use of the expression, is thus not the product of inference and construction, but it is immediately present in every presentation of a surface. Though it may not be the object of our attention and measuring apprehension, every space perception pre-supposes extension in all directions.

THE GEOLOGY OF THE LAKE WENDIGOKAN REGION.

By Elwood S. Moore, M.A.

During the summer of 1906 I had the privilege of conducting a geological exploration of the Lake Wendigokan Region. The work was done in the interests of the Bureau of Mines of Ontario, and under the direction of T. W. Gibson, Deputy Minister of Mines; the object in making the exploration being to secure a report upon the iron deposits occurring in that field. Prior to that time no detailed work had been done in the district, and I therefore submit this paper as one embodying the results of some original investigations in the Science of Geology.

Although no detailed work had been done in the region, J. W. Bain calls attention to its iron ranges in a short article* on the iron ranges of the Nipigon region, Dr. W. A. Parks mapped it on a large scale, and briefly described it in his summary report for the Canadian Geological Survey,† and prospectors, chiefly those of the Algoma Commercial Company, had located mining claims there. Dr. Parks' map was very serviceable as a guide, and the map of the Algoma Commercial Company's surveyed claims proved very valuable when fixing the geology in the field.

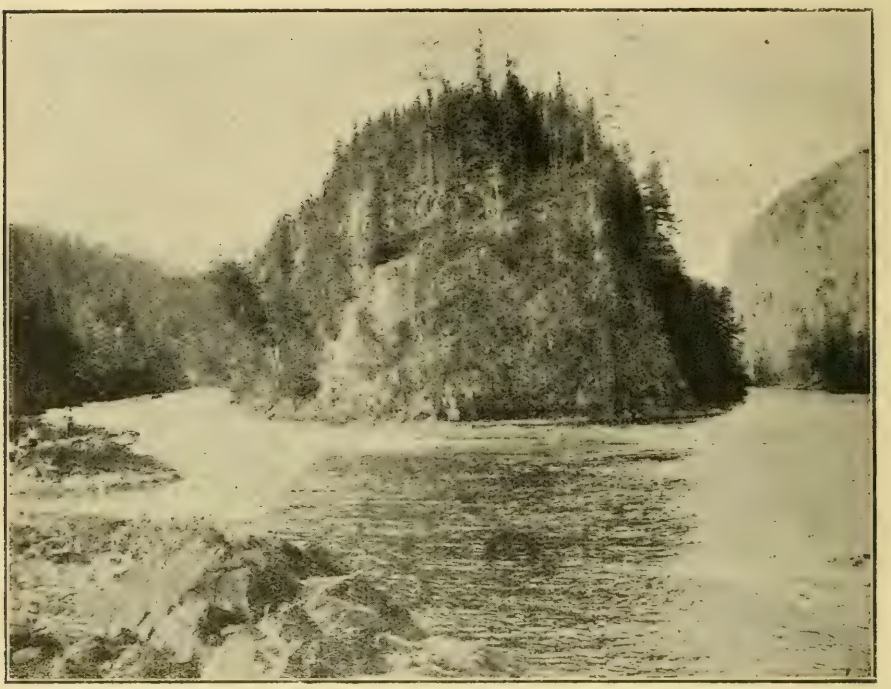
I should appear very ungrateful if I were to neglect to acknowledge, during the preparation of this paper, the efficient services of my classmate, Mr. T. L. Goldie, B.A., who acted at topographer during the field season, or fail to express my indebtedness to Dr. A. P. Coleman for his many valuable suggestions in regard to this subject and the generous interest he has shown in my work.

The Geographical Position and Extent of the Region.

The major part of this discussion is confined to the area indicated on the accompanying map. This area is about twelve miles in length by five in width, and includes Lake Wendigokan, a fine blue lake dotted with evergreen islands, and lying among hills of green schist and drift. Its position is about ten miles from the mouth of the Sturgeon River, which enters Lake Nipigon near the centre of its east shore, and to reach

* Report of the Bureau of Mines, 1901.
† Report of the Canadian Geological Survey, 1901.

the region one must leave Nipigon village and make a canoe trip of about seventy-five miles. This distance includes forty miles up the Nipigon River, twenty-five on Lake Nipigon, and ten up the Sturgeon River to the foot of the long rapids. To reach Lake Wendigokan from the Sturgeon it is necessary to portage about three miles east from the foot of the



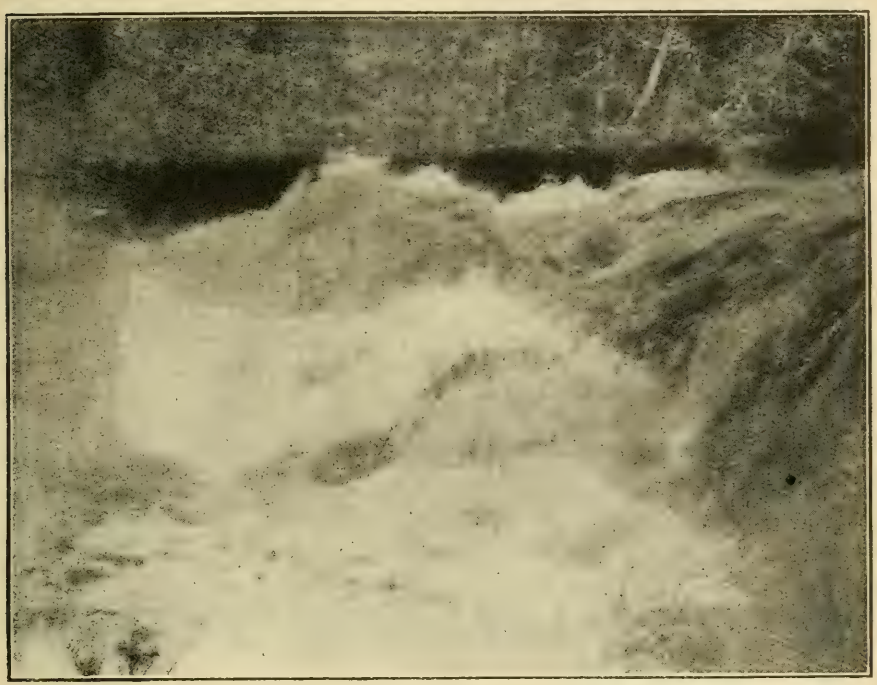
Split Rock, Nipigon River.

rapids to Lake Corrigan. From the latter another portage about a mile long leads to a small marshy lake lying to the southeast, and from this lake it is but a short distance to Wendigokan.

TOPOGRAPHY.

If it were not for the hills of intrusive eruptive, later than the Huronian rocks, the region lying east of Lake Nipigon might be considered a peneplain. But these masses rise here and there, forming great irregularities, on what would otherwise be approximately a plain formed by erosion. The long rapids on the Sturgeon River with a difference in elevation between the head and foot of about 80 feet, are due to one of these eruptive masses lying across the course of the stream. The portage trail from

the river to Lake Corrigan begins on comparatively low sand plains, but rises in crossing this same mass to about 1,100 feet above the sea and 200 feet above the foot of the long rapids, and then descends to Lake Corrigan, which has an elevation of about 1,020 feet above the sea-level. To



First Falls on the Sturgeon River.

the north of this lake a large hill of conglomerate rises about 250 feet above its surface.

Between Lakes Corrigan and Wendigokan there is no great difference in level, though the portage between Wendigokan and the small lake to the west on the portage route crosses a divide. The water flows from this small lake to Corrigan and from there a short distance northwest to the Sturgeon, while the creek leaving the northeast bay of Wendigokan flows northward and westward, but reaches the river much higher upstream than the outlet of the other creek. Between Clear Lake and Wendigokan there is only about twelve feet difference in elevation, and Clear Creek flows over sand and gravel, which circumstance, combined with the fact that it has its origin in lakes lying in the same material, makes its water remarkably clear.

In the neighborhood of Clear Lake there are morainic hills rising from 35 ft. to a much higher elevation in the distance, and low sand plains from 6 ft. to 10 ft. above the lake, while around Wendigokan the sand plains rise from 15 to 30 ft. above that lake. To the north of the latter green schist hills rise about 125 ft. and to the westward 175 ft. above its surface, while to the south moraine covered hills reach an elevation of

Lower Falls in Long Rapid on Sturgeon River.

from 80 to 240 ft. Much swamp and many small lakes lie to the south of Wendigokan.

Watson or Rocky Lake, as the latter name might indicate, lies in a rocky hollow surrounded by green schist hills, which are rather low on the south side, but on the north have an elevation of about 135 ft. above the lake. This lake drains south-westward, and probably by Sand Creek. There is little difference in the elevations of Watson, Wendigokan and Tallon Lakes.

The country as a whole is not nearly so rough as most of the region nearer the coast of Lake Superior, and it seems to grow less rough towards

the eastern end of the district explored. It should be added that the figures given here for the different elevations were largely obtained by use of the aneroid barometer, and can, therefore, be only approximate because of the conditions under which the aneroid was used.

A HISTORICAL GEOLOGY SKETCH.

The earliest geological records found in this region are in the series of extrusive volcanic rocks which correspond to the oldest known rock series of the continent. There was during the earliest period recorded by rocks, a great series of surface lava flows, as shown by the porphyries and by the amygdaloids found south of Wendigokan and again to the west on the shore of Lake Nipigon, where the pillow and brecciated structures are also well developed in the greenstones. Along with the lava flows, there were probably deposits of ashes and other volcanic detritus which later became consolidated, forming taconytes, which may be seen along the south side of HF16. These rocks are very common in some of the iron formations of Minnesota and are frequently described in the geological reports of that state. While the surface materials were being extruded and possibly after they had ceased to be poured out, there were igneous rocks cooling beneath the surface, where they remained until later exposed by erosion. These rocks are now represented by the quartz diorites which are rather widely distributed in the region.

After the great period of volcanic activity there appears to have been a prolonged period with little evidence of vulcanism during which the rocks were subject to the action of air and water which decomposed them and carried the solutions leached out to the sea or inland waters. There is no direct evidence here that these waters were marine, though the pressure of limestone in some other places, which may of course be a chemical and not a marine organic deposit, is strongly in favour of this assumption, and the conditions which followed are simpler and more easily explained by considering that these deposits were made in the shallow arms of the sea or in partially or entirely enclosed bodies of sea water shut off by low barriers. The sea must be considered as covering the Wendigokan region before the next formation was deposited.

On account of the presence of much carbon dioxide which is supposed to have been present in the air and waters at this time, the materials would be largely precipitated from solution as carbonates mixed with more or less mechanical sediments in the form of fine clastic material. It is quite probable that there was considerable precipitation while the volcanic, fragmental materials were being deposited, because of the

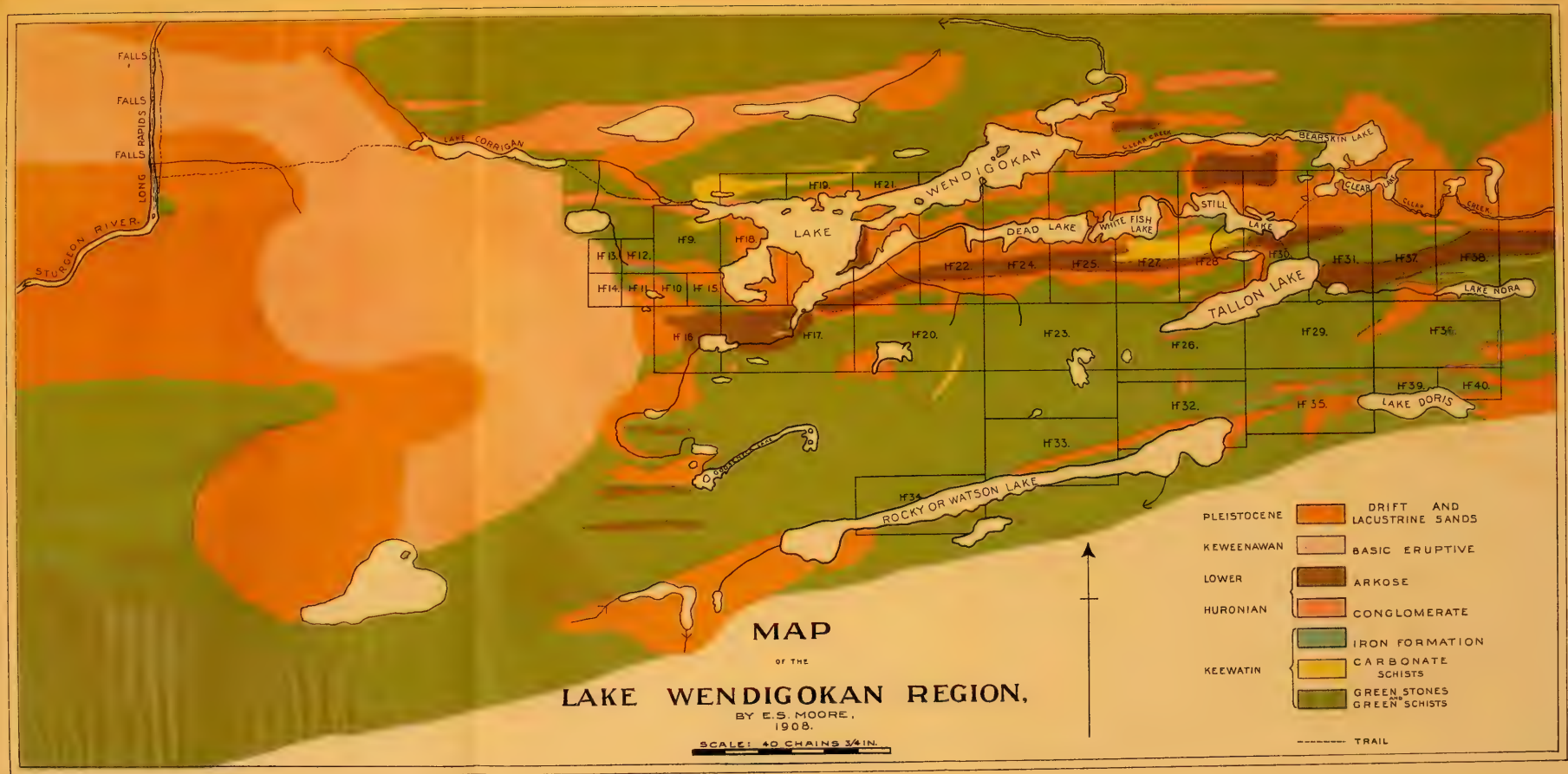
intimate mixture of the iron carbonate with the constituents of these rocks, though in a loose rock of this sort the waters would have free access to the internal spaces and could easily deposit the chemicals at a later date. The materials which were laid down as here described gave rise when metamorphosed to the carbonate schists.

It is probable that later the attitude of the land to the sea changed still more, and that deeper water covered the rocks so that purer chemical deposits of iron compounds and silica were formed, giving rise to the iron ranges, which have since their formation been subject to much metamorphic action. These sediments seem to be the latest of the Keewatin system, though in my previous article on the iron ranges of this region* I stated that the more extensive outcrops of the arkoses should probably be placed in this system. From further study of these rocks outside of this particular district I concluded that they belong to a later system.

After the Keewatin system was complete, great folding and metamorphism of the rocks took place, forming schists by crushing and shearing, and the region emerged from the sea so that it was again subject to erosion. It is probable that the intrusion of the Laurentian rocks was responsible for much of this dynamic action. These rocks are scarce in this district, being only seen as a few small dikes, unless there belong with them the quartz diorites whose age is by no means certainly known and which are rather widely scattered in the region; but the Laurentian rose much more prominently to the north and south.

At the close of the Laurentian period of eruption great erosion of the land surface occurred, and after a period the sea again transgressed on the land. The materials worn from the surface were then laid down on the Keewatin and Laurentian rocks as conglomerates and other mechanical sediments, the coarse conglomerates being formed along the coast and the less coarse farther out to sea. Probably some of the arkose found quite commonly in the district, and just south of the most important band of conglomerate, was formed contemporaneously with the latter. If the sea at the end of the erosion period which succeeded the formation of the Laurentian rocks encroached upon the land, on the surface of which there was much fragmental material, as there probably would be after a period of dynamic action like that of the Laurentian, the water would sort this, depositing the coarser near the shore and the finer in deeper water. In this way the conglomerate could be formed and if the less coarse material suffered comparatively little from the water action it might

* Report of the Bureau of Mines, 1907.



MAP

of the

LAKE WENDIGOKAN REGION.

BY E.S. MOORE,
1908.

SCALE: 40 CHAINS 3/4 IN.

give rise to some of the arkose. The loose materials on the land surface, covered and sorted by the sea, would of course be supplemented by those brought down by the streams, but it is probable that during a time of submergence the streams would be unable to transport much coarse material, and that so long as the lands remained comparatively low, the coarser stuff would be left on the surface until such time as the land should begin to emerge and the streams be rejuvenated, when it would be carried down and deposited in the retreating sea. I think it is quite probable that much of the material which formed the arkose was deposited in the retreating sea and thus suffered little water action, because if it had been deposited at the same time as the conglomerate it must certainly have been more water worn than it is, as many of the hard conglomerate pebbles are well rounded. It is quite probable that part of the arkose was formed by the crushing and weathering of granite and quartz-diorites, and that it is a land formation of fragmental materials washed from the high to the low ground after the emergence of the land, but the close relation to the conglomerate seems to show that it was not all formed in this way. Whatever the origin, it is significant that the formation lies to the south of the great ridge of conglomerate, where the sea covered the land, and seems to be found only where that rock is well developed. The great band of coarse conglomerate stretching all along the northern side of the map and much farther east shows that the coast line was for a considerable period near this band.

The arkose appears to be the last of the Lower Huronian series and the latest consolidated clastic formation of this region. Though this and the earlier rocks have since their origin been subject to great erosive action by which large masses, many hundreds of feet, have been removed and been subject to other great changes through metamorphic agents, there is no direct evidence that they have since Huronian times been covered by the sea or any other extensive body of water for a great period of time. It is possible that the later eruptive rocks were intruded into sedimentary rocks which were post-Lower Huronian in age, and which have since been removed by erosion, but there is no proof that this occurred. Probably during the Keweenawan period a large mass of diabase was intruded into and through the rocks of the region west of Lake Wendigokan and this with similar intrusions in the surrounding districts exerted considerable metamorphic action on the older rocks.

Between the Keweenawan and Pleistocene none of the great periods are represented by rock systems, but the Pleistocene is well marked by sand plains and various kinds of drift deposits. All the ages have left no trace of life in the rocks of this region unless it be in the Carbonaceous

schists and slates which occur with the iron formation, and the only definite life history to be recorded is that of the recent plants and animals, which are similar to those in many other regions and need not be discussed in detail here.

Some recent structures of interest were observed in the diabase at the foot of the long rapids on the Sturgeon River. These were three pot-holes from 12 to 18 inches in depth and about six inches in average diameter. In each hole a rounded stone and some gravel were found and these had been used by the water as tools with which, in its circular motion, it ground out the cavities. One of these holes bore a striking resemblance to a large iron mortar and pestle used in a laboratory for pulverizing rock. In one of them the rounded stone had become so tightly wedged that it could not be moved, and the growth of the hole was, therefore, terminated.

CLASSIFICATION OF THE ROCKS.

From what has been said in the preceding section the rocks can be tabulated in ascending order thus:—

Pleistocene:—Drift and lacustrine sands.
Keweenawan?:—Basic eruptive.
Lower Huronian: { Arkose / Conglomerate.
Keewatin: { Rocks of the iron formation. / Carbonate schists. / Green schists, greenstones and banded arkose and slate.

On the accompanying map the greenstones, green schists and banded arkose and slate are mapped together because of the impossibility of separating them. As the individual formations can best be considered separately they will be taken up in ascending order and where necessary some further notes on my reasons for placing them in their respective positions will be given.

GREENSTONES

These rocks may be readily correlated with the ancient greenstones so frequently mentioned in the geological reports of the Cobalt, Eastern Ontario and Michipicoten regions and they lie at the bottom of the rock series around Lake Wendigokan. They consist of porphyries with large crystals of plagioclase or hornblende, of amygdaloids containing amygdules, generally of quartz or calcite and ancient quartz-diorites. A specimen

of a porphyrite taken just east of the southwest corner of location HF19, weathers brown on the surface to a depth of about half an inch. It is very compact and on the fresh surface is light grey in colour, and shows many crystals of pyrite. In thin section it shows a great deal of pyrite, some chlorite, very little hornblende, and large crystals of plagioclase badly decomposed. It has been suggested that the pyrite in these Keewatin rocks is of secondary origin, having been derived from sulphates through reduction by carbonaceous matter. If there were life in the waters at that time, this is doubtless the best explanation for the presence of the pyrite in the sedimentary rocks, but it is much more probable that in these eruptive rocks the pyrite is pyrogenetic in origin. This pyrite is probably the source of the brown iron oxide which covers the surface of the rock.

The amygdaloidal rocks which are most frequently found west of Tallon Lake are greatly weathered, light or dark green rocks, generally having their cavities filled with quartz or calcite. It is noticeable that calcite is very common among many of these older rocks, filling cracks and cavities, and its presence is readily detected by the action of acid on the rock. It might be that this calcite has been recrystallized from portions of limestone which at one time covered the greenstones and has since been weathered away. This was suggested by Professor Miller's description of the relation between the greenstone and limestone in Eastern Ontario. On the other hand it may be a much later deposit from percolating waters. A thin section from the amygdaloid occurring a short distance from the southwest corner of location HF23 shows it to be a basic lava with many amygdules filled with chlorite resulting from the decomposition of minerals formerly contained in the cavities. Along the south side of HF26 a greatly weathered greenstone occurs which exhibits no characteristic features in the thin section. In location HF34 there was found a mixture of greenstone and green schist, some of the former in small patches showing the lava pillow structure. Near the southeast corner of HF16 there is a rock quite massive in appearance, weathering brown and containing a good deal of pyrite. In the thin section it exhibits a structure with small circular masses like that of the taconytes so frequently described and pictured in the Minnesota state reports. Though it is greatly weathered the structure shows that it is a fragmental rock and of volcanic origin. It is a type of tuff and since it contains much iron carbonate it seems to be closely related to the carbonate schists described later in this article and these probably grade into one another. However, its massive structure and much fresher appearance seem to separate it from the typical carbonate schists.

The quartz-diorites of the region may not be of the same age as these other greenstones, but as they cannot be classed by themselves, they are put in here. They are most plentiful west and south of Wendigokan Lake, and appear as rounded or irregular masses. No thin sections of these were made, but I found a typical quartz-diorite pebble in the Huronian conglomerate, and it will be mentioned in connection with that rock. As already stated these diorites may be of Laurentian age. The greenstones are not as widely distributed as the green schists and are most common south of Lake Wendigokan. These rocks have been the origin of some of the schists which grade into them, but portions of them have resisted the shearing action and largely retained their original massive condition. They have also exerted quite an influence upon the strike of the schists in their neighbourhood.

THE BANDED SLATES AND ARKOSES.

The slates are widely distributed but in small masses. They almost invariably occur with the iron range and although a good indication of the presence of that formation in the immediate neighbourhood, they may occur without it. On account of their very intimate connection with the iron range, it is difficult to say to what extent they should be considered a part of it. They are black or sometimes grey on the weathered surface, and are made up of argillaceous deposits. They occur interbanded with streaks of the jasper and banded silica, and interbanded with the silica or jasper which conditions show that there was probably a frequent change from a predominance of chemical sediments to that of mechanical sediments during the formation of the iron range. And the interbanding of the slate and arkose shows that there were frequent variations in the coarseness of the mechanical sediments. This might be accounted for by supposing the attitude of the land to the sea changed frequently, that the rate of disintegration of the rocks of the land varied often, or that the strength of the currents of the Keewatin rivers was not uniform at different times. Since these deposits occurred in bodies of shallow water, I think that the banding is due chiefly to the difference in the strength of the currents of the streams at different times and partly to the variation in the rate of weathering the land surface, which variation might be due to change of climatic conditions, and with that the change in the amount of vegetation which may have covered the land surface at that time.

A thin section of a specimen taken near the jasper in location HF_{38} shows interbanded slate and arkose. The slate is too fine-grained to show many distinctive features, but it contains considerable pyrite in very

small grains and many very small pieces of feldspar. The arkose bands show distinct angular fragments of quartz, pieces of feldspar, much pyrite, chlorite and fine-grained material. The bands of slate and arkose vary greatly in width, some being as much as three-quarters of an inch in width, while others are extremely narrow.

There are, besides those associated with the slates, some arkoses which in the field have been placed with the schists because of their schistose condition and the impossibility of separating them from the schists, but their age would place them with the arkoses of the Huronian.

THE GREEN SCHISTS.

These very old rocks are green from the presence of chlorite and secondary hornblende. Their origin is partly from sheared greenstone and probably partly from ash rocks and other volcanic detrital materials. They do not now possess their former constituent minerals and are entirely unsuitable for study in thin section.

On the portage between Lake Corrigan and the small lake to the east there is an old hornblende schist green with chlorite and containing much calcite in the cracks. Along the southern side of location HF20, there is a distinct hornblende schist of which quartz and hornblende are the chief constituents, and south of the northeast corner of the same claim there was taken a specimen of sheared porphyrite which had contained large cystots of plagioclase. Farther to the south again a large schist hill about 100 ft. high has originated by the shearing of a hornblende porphyry.

No estimate of the thickness of these rocks can be formed.. The dip is usually about 90 degrees, but in the southern part of the region it is nearly 70 degrees southward. The strike in the southern part is about 70 degrees but about 600 paces east of the southeast corner of location HF31 the strike changes from 70 degrees to about 95 degrees and this strike is common in the northern part of the region.

THE CARBONATE SCHISTS.

The name *carbonate schist* is applied to those schists which are distinguished by their quartz crystals, greatly weathered condition, and yellowish brown colour. They are sheared rock containing considerable carbonate and oxide of iron and correspond closely to the Wawa tuffs of the Michipicoten region.* In the Wendigokan district it is impossible

* Bureau of Mines Report, 1902, "Michipicoton Iron Range."

to say just how they stand in relative age with the other rocks, but I have placed them in the same relative position as the Wawa tuffs whose age has been pretty well fixed. Along the north shore of the lake they occur intermingled with the green schists and though they appear to be interbedded with the latter the close folding is probably responsible for this condition.

The opalescent quartz crystals stand out prominently from a fine grained indefinite ground mass of iron compounds and feldspar. The iron is in the form of hematite and carbonate, either siderite or ankerite, the carbonate giving a very active effervescence with hydrochloric acid. The carbonate appears to have given rise to the oxide by oxidation. An analysis of a specimen of this rock taken south of Whitefish Lake gave twenty per cent. of iron, mostly in form of hematite.

The distribution of these schists is quite general, but they are found in small quantities. No doubt they were widespread at one time, but owing to their greatly weathered condition they have largely disappeared. Their strike corresponds closely to that of the associated rocks, being about 70 degrees in the southern part of the region, and east and west in the northern part.

THE IRON RANGES.

When Dr. Coleman had worked over the iron ranges on Sand Creek and Sturgeon River it was expected that the three rather distinct ranges found there would be continued beyond the basic eruptive sheet to the northeast. This proved to be only partly correct. On Sand Creek and the Sturgeon River the ranges are clearly separate, and one is a considerable distance from the other two, while near Wendigokan there are no such definite ranges, the outcrops being more scattered. The two districts are alike in respect to the presence of jasper and hematite in all of the bands and of magnetite in two of the bands of each district. The formation of magnetite must be ascribed to some local reducing agent, probably carbonaceous matter, as there are no such conditions as those Dr. J. M. Bell reports as always present where magnetite was found in the Michipicoten region, viz., excessive metamorphism or the proximity of some intrusive mass, which had caused reduction by heat effects. During last summer, while working in another region, I saw several dikes cutting the iron range, and in every case the formation close to the dike contained magnetite instead of the red jasper found a short distance away on either side of the dike. It is probable that the carbon contained in the black slates which are so closely associated with the jasper in the Wendigokan

region might, under certain conditions, reduce the hematite to magnetite. In an analysis of a piece of the slate from the iron range on Whitefish Lake there was found a loss of 6.02 per cent. on ignition, and this loss can be mostly attributed to the presence of carbon. In some places these slates are quite abundant in the iron formation, but in others there are large masses of banded silica and jasper without any mechanical deposits and these conditions must be accounted for in much the same way as the interbedding of limestone and shale. The chemical precipitates of white silica and jasper must have been deposited, like limestone in comparatively clear water, and the slate, like shale, in water carrying much mechanical sediment.

Some writers have suggested that the chemical sediments of the iron formations were deposited from superheated sea water. It is improbable that the sea over any great area was at a high temperature during this time, nor is this conditions necessary, because silica can be deposited in the amorphous condition from water which is not at a very high temperature, and if deposited in the amorphous condition it would no doubt undergo a re-arrangement of its molecules and take on a crystalline condition under the action of metamorphic agents, just as the amorphous silica of the skeletons of some animals becomes crystalline. Or on account of the presence of alkalies in the sea water the silica might be deposited from solution of the alkali silicates at ordinary temperatures, A boulder containing specular hematite and quartz crystallized together was found in the region, and it is interesting in showing how these substances crystallize from water at a high temperature. I think it quite correct to assume that the water was hot in this case, because the silica is in the form of perfect quartz crystals and the fine crystals were formed in a cavity so that they have not been subject to metamorphic influences since their formation.

The strike of the iron formation in the northern part of the region is nearly east and west, and in the southern part about 70 degrees. This difference in strike brings the eastern ends of the bands rather close together, while they are some distance apart at the western end. The dip of most of the bands is nearly 90 degrees, though in location BT01, the dip is about 75 degrees north, and in HF35 70 degrees southward, while between the two outcrops a narrow band dips at about 90 degrees. This condition suggests a closed fold having the anticlines removed by erosion, and the outer limbs of the anticlines dipping north and south and the inner ones standing vertically, but in the other bands of the formation the dip is almost always about 90 degrees or indefinite, and I concluded that the folding was on a smaller scale and more complicated. The rocks

have all suffered such intense metamorphism and such extensive erosion that it is impossible to trace the structures with any degree of satisfaction, but it is possible that a more rigid investigation of the region might show that the structure could be best represented by an anticlinorium, with the anticlines all truncated by erosion. Within the banded silica and jasper the folding and crumpling is very elaborate, and shows the application of pressure from several directions. In some cases the jasper is folded while the slate on either side of it is not, and in a few cases the slate is folded while the jasper interbanded with it, shows no sign of folding on the surface. These conditions may be explained by supposing the folding occurred in different planes or that often the jasper folded while the slate, being a softer rock, mashed and sheared, instead of folding.

There are some fine bands of iron formation in the region but the percentage of iron in them is low. A number of analyses were made by A. G. Burrows, Provincial Assayer, of specimens from various parts of the ranges, and the results were quite disappointing, as scarcely any of them showed enough iron to make any parts of the ranges of commercial value.

DISTRIBUTION OF THE IRON RANGES.

There are three prominent outcrops of the iron formation, one west of Lake Wendigokan, another on Still Lake, and one northeast of Watson Lake. Besides these, there are a number of lesser outcrops occurring in various parts of the region, but they are unimportant. The outcrop west of Lake Wendigokan is of considerable proportions and lies in locations HF13, 12 and 10. It is composed of grey slate and jasper in parts very finely banded and the highest assay of specimens taken was 36.56 per cent of iron in hematite. Much of the mass lies under swamp and drift; part of the latter having been removed by trenching, but the part of the iron formation exposed is so hard and so low in iron that these qualities combined with the absence of any particularly favorable geological conditions preclude any possibility of finding an ore body associated with this outcrop. The jasper becomes greatly mixed with schist before running into the eruptive sheet to the west, and also at the east end before disappearing under the drift. Just south of this outcrop and in location HF11 there is a small mass of banded magnetite and jasper very similar to that found in the southern range near Poplar Lodge.

On Still Lake in the old location BT01, there is a large outcrop of iron range. A large portion of it is excluded from view by drift and swamp, ut it extends through from Still to Whitefish Lake, and although at either b

end it is not more than from 15 to 20 paces wide, it widens out in the widest part to about 160 paces and disappears into the lake on the north side. This is the finest outcrop of the formation found in the region, and though the best analysis made only gave 36.86 per cent. of iron in the form of hematite and thus shows this to be too low in iron to be considered of commercial value at the present time, it may some day yield some low grade ore. The strike of the land is nearly east and west, and the dip 75 degrees north so that it dips under the lake and there is a possibility of a concentration of ore having occurred beneath the lake, though there is an absence of very high ground where the iron range outcrops as there is as a rule where the large bodies of ore occur in Canada and the United States.

Northeast of Watson Lake and extending from claim HF32 through HF35 and 39 there is a band of iron range which mixes with schist at both ends and appears at intervals in the swamp. It is composed of magnetite and jasper bounded on both sides by a green slaty schist. The best sample of magnetic oxide from this outcrop analyzed 48.9 per cent. of iron, showing that it is high enough in iron to make ore, but the quantity of the formation exposed is too small to produce a large amount of ore. There is, however, quite a strong magnetic attraction in the swamp which runs along the north side of the outcrop, and it is barely possible that magnetic survey work might reveal the existence of an extensive mass of the formation which is now excluded from view.

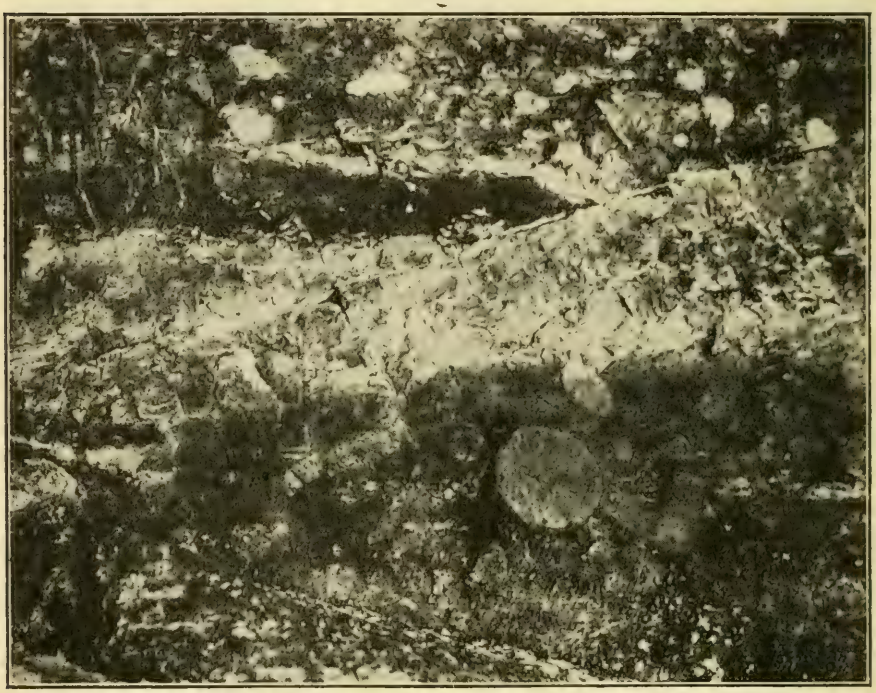
A small outcrop of jasper and magnetite on Watson Lake may represent a continuation of the band lying farther northeast. The small masses scattered over the region are of jasper and hematite enclosed in slaty schist and in most cases with vertical dip.

THE LOWER HURONIAN CONGLOMERATE.

The conglomerate appears in nearly every part of the region, but the most important outcrop lies north of Lake Corrigan. There a great band of it rises as a hill over 200 feet above the lake, and it can be traced by less prominent but still larger outcrops away to the east. The other outcrops are scattered over almost all the remainder of the region, but they are mostly small and represent remnants of the once widespread formation, now left in small synclines in the older rocks. The formation has been subject to some of the same forces which folded the older rocks and has much the same strike as they have. It is also in some places quite schistose with pebbles in the form of nearly perfect lenses.

Like the iron formation, the Huronian conglomerate fixes a definite

stratigraphical horizon. It contains pebbles of every older formation represented in the region besides some of rocks which are not common there. The largest and most prominent pebbles are granite, but there are also pebbles of greenstones, quartz-diorite porphyry, green schist, carbonate schist and jasper, cemented together by a matrix of fine grained green material. A thin section of one pebble contained large phenocrysts



Lower Huronian Conglomerate, Lake Corrigan

of plagioclase showing the polysynthetic twinning, crystals of hornblende, some quartz and fine grained material, the whole being considerably weathered. On the line along the east side of location HF27 and just south of Whitefish Lake there is some conglomerate containing pebbles of the carbonate schist. These are fairly well rounded, but have been somewhat deformed by shearing. They lie in a matrix containing a good deal of iron carbonate and as the outcrop is beside an exposure of the carbonate schist it appears that the conglomerate has been derived directly from this rock.

The conglomerate north of Wendigokan contains less jasper and

more large granite pebbles than that south of the lake and away to the east. This condition is due to the origin of the material composing the large band to the north being largely in the rocks north of the iron range exposures, while that farther south has been derived from the outcrops of the formation in that part of the region. And I think it also favours the suggestion already made that the material composing this rock was largely the loose mantle rock which covered the land when the sea transgressed upon it, at the close of the Laurentian period. After such a period of vulcanism as that which marked the Laurentian, the rocks would doubtless be in a shattered condition and readily disaggregated by weathering. The coarseness of some of the conglomerate shows that the boulders contained in it could not have been transported any great distance by water unless the land to the north were very much higher than it is at the present time, and the streams had very strong currents. The presence of these large granite pebbles when extensive exposures of granite are not found within many miles to the north or south is significant, though these may have existed, been eroded and covered by later formations. Should this suggestion fail to satisfy the conditions, their presence might be explained by supposing they were carried from the granite outcrops to the north by glacial action. There are no direct evidences of glacial conditions in this region during the Huronian period, but since there are evidences of these conditions in other parts of Ontario, it may not be unreasonable to suppose that they also existed in this more northern region.

THE HURONIAN ARKOSE.

The origin of this formation has already been discussed in the outline of the Historical Geology of the region. It is quite common around Lake Wendigokan, where it appears to exist in synclines of the older rocks, but scarce in the iron range regions around Sand Creek and Sturgeon River. The absence of much jasper in the rocks, though some is found, and the presence of arkoses closely associated with the slates and iron formation, have previously been given as reasons for placing these rocks in the Keewatin system, but the nature of the rocks, their association with the conglomerate, and the absence of arkose pebbles in the conglomerate seem to be better reasons for placing them in the Huronian. These are generally massive grey rocks weathering brown on the surface in places, and they differ from our more recent arkoses in being very firm and compact. They often appear as rounded hummocky masses retaining the smoothed surface made by glacial action. In some of the hand specimens, quartz fragments can be detected readily with the naked eye, and in the field the rock has a

strong resemblance to a quartz-diorite. As these rocks make fairly good thin sections, a number were made and in every case the section showed that the rock was largely made up of quartz fragments. A thin section of a specimen from the long point running out into Lake Wendigokan on the west side of HF21, contains a few fragments of hematite, and a hand specimen from some similar arkose on Lake Wawang, much farther east, shows some small fragments of the same mineral. Where the latter specimen was taken the arkose is rather coarse and is closely associated with some of the conglomerate very rich in jasper pebbles. An interesting specimen from near the middle of the south side of location HF19 on Lake Wendigokan, very much resembles a conglomerate on account of some concretionary structures which in the hand specimen look like pebbles. Under the microscope there may be seen small mosaics of quartz among the angular fragments, also badly decomposed plagioclase, some zoisite, orthoclase and chlorite. In some of the specimens, part of the quartz fragments are fairly well rounded, showing water action. It is a little hard to account for so much quartz in these rocks unless they originated from granites and were carried down from the north by streams, but the fact that the quartz is so much more resistant than the other minerals and would, therefore, remain while the others would be decomposed and carried away, would help to explain this condition. Much of the sand so plentiful along the streams and lakes in this region probably originated from the decay of these rocks.

THE KEWEENAWAN;—BASIC ERUPTIVE.

The only outcrop of the post-Keewatin basic eruptive found in the region is that west of Lake Wendigokan and crossing the trail between the Sturgeon River and Lake Corrigan. This rock is responsible for the long rapids on the Sturgeon, and it is quite probable that the large outcrop extending some distance along the east shore of Lake Nipigon is a continuation of the same mass almost directly westward from where it crosses the Sturgeon. It has proved difficult to fix definitely the age of this rock, because it represents the only system found in the region between the Lower Huronian and Pleistocene, but its strong resemblance to other Keweenawan rocks of the Nipigon region are very much in favour of placing it in the Keweenawan system, and though there is plenty of room for difference of opinion on the classification, in my opinion that is the system to which it belongs.

This mass of eruptive has some appearance of being an intrusive sheet with its broad flat areas on top and, though the contact is usually

excluded from view by drift, where it comes in contact with the iron range in locations HF13 and 14 the diabase has the appearance of having flowed out over the older rocks leaving them little disturbed, as the iron range does not appear to have been bent up and the diabase seems to lie on top of it. If it were a sheet it would grow finer grained toward the top, which it does not do over much of the outcrop, though it is probable that a great deal of material has been eroded from its surface and the portions of the mass now remaining are quite below the original surface. There are no evidences of scoriaceous, vesicular, amygdaloidal or pillow structure which would suggest a surface flow, but on the contrary much of the rock is quite coarse grained. Considering the irregular form of the mass,

Diabase Hills on the Nipigon River.

its general irregular surface, when contrasted with the level surface of the diabase sheets farther south along the Nipigon River, though there are flat areas on top, the failure of the rock to grow fine-grained towards the surface, the lack of columnar jointing so common in the silts of the region, and the general relations between the eruptive and surrounding rocks, I think it can safely be called a batholith or bysmalith, more nearly the former than the latter.

This structure was intruded into overlying rocks, some of which may have been post-Lower Huronian and which have since been eroded away. It has broken the continuity of the conglomerate, the arkoses and possibly the iron formation, leaving remnants of these formations to the east and west of it. It is possible that the conglomerate and arkose completely covered this mass at one time, but its intrusion into these formations so weakened them that they have been easily removed by erosion. In the field this rock is readily mistaken for gabbro, but as the specimens of it give fairly good thin sections, it is easily recognized under the microscope as an olivine diabase so characteristic of the Keweenawan rocks of the Nipigon region as well as of these in other parts of Ontario. The thin section shows a well developed poikilitic structure with the augite crystals enclosing slender, lath-shaped crystals of plagioclase, poly-synthetically twinned. Much of the augite gives very low polarization colours these frequently being grey or drab. Besides the plagioclase and augite which make up the larger part of the rock there are small amounts of secondary hornblende, magnetite, biotite and olivine, the latter generally changing to serpentine. There is absolutely no quartz in the section examined and this would be another example in favour of the principle for which Rosenbusch has so long contended in spite of examples which definitely proved his contention wrong, viz., that it was chemically impossible for quartz and olivine to form together from the same rock magma.

THE PLEISTOCENE PERIOD.

The work of the glacier is much in evidence in the Wendigokan district. The results of its work are shown in the hills of terminal moraine, the long ridges of stratified drift, the stretches of swamp and the broad sand plains. Associated with these deposits there are numerous boulders, and west of Lake Wendigokan there are some which contain hematite, and one was found containing banded silica and pyrite, the latter being very much like some of the iron formation about fifty miles to the north and it probably came from that locality. Around Clear Lake the morainic hills are very conspicuous, and south of Wendigokan some large hills composed largely of moraine, but partly of rock, reach an elevation measured by the aneroid, of 240 ft. In the latter district there are beside the irregular morainic hills, some long ridges which are not traced out carefully, but on account of their partly stratified structure and serpentine outline, appear to be eskers. One of these serpentine ridges crosses the north and south line along the west side of claim HF16 and extends in a general northeast and southwest direction. A number of other ridges in the region, if studied closely, might prove to be eskers, but little time

was spent in examining them because our work in the region was chiefly that of examining the iron ranges.

The most interesting glacial features observed in the region are the sand plains formed by the glacial lakes. These plains are well developed near Lake Nipigon, and can be seen all along the Sturgeon River beyond the high banks of sand. Around the foot of the long rapids on this river there are some ridges of stratified silt which may have developed by the cutting away of portions of the plain by erosion, thus leaving these ridges as remnants, but I think, after as careful an examination as could be made, since the sands were thickly covered with vegetation, that these ridges represent sand bars which were formed by the waves and shore currents of the glacial lake across the opening of its bay which stretched inland a short distance to the northeast, and a long way up the channel now occupied by the Sturgeon River. In this same region and a little farther south along the river there is some well stratified silt, coarse, and very coarse sand quite typical of the beach or shallow water deposits of a lake. On the portage between the Sturgeon River and Lake Corrigan, the sand plains reach an elevation of about 125 feet above the foot of the long rapid and 1,035 feet above sea-level. These plains are found farther east beyond the highest part of the diabase outcrop and may be seen around Lake Wendigokan at between -10 and 30 feet above the lake, while around Clear Lake they are mostly not more than -10 or 15 feet above that lake and about 1,040 feet above sea-level. There seems to be some difference of opinion among geologists as to which of the glacial lakes formed these sand plains. At least some of the Canadian geologists* hold the opinion that Lake Warren was responsible for them, while the Americans† do not consider that Lake Warren ever covered that part of the country but that the lakes which extended over Lake Superior and the surrounding region were Lakes Algonquin and the great Nipissing Lakes, the former being more extensive than the latter and extending as far north as Lake Nipigon.

These sand deposits represent the shallow water formations of one of these great glacial lakes, and although during the summer of 1907 we found sand plains with greater elevation than those extending to the east as far as Battle Island Lake, on the Sturgeon River, at the time these plains around Wendigokan were studied, they proved that a great bay of the glacial lake extended up the present channel of the Sturgeon River and farther inland from Lake Superior than in any region then explored.

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* Coleman, Bureau of Mines, 1907, p. 135.

† Chamberlin & Salisbury, Geology III, Earth History, pp. 399-400.
Goldthwait, Bull. XVII, Wis. Geological Survey, 1907.

NOTES ON THE OPHIURIAN GENUS, PROTASTER, WITH DESCRIPTION OF A NEW SPECIES.

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MANY diverse Palaeozoic Brittle-stars have been ascribed to this genus, and, although a comparatively recent revision is available, the classification can not yet be said to be satisfactory. The reason for this is to be found in the poor state of preservation of most examples and the consequent lack of knowledge of the details essential to a rational classification. It is believed that some additional light is thrown on the structure of these forms by the examination of the species about to be described. It is thought advisable therefore to preface the description proper by a short account of the development of our knowledge of the genus.

The genus *Protaster* was erected by Professor Forbes for the reception of a species *(P. sedgwicki)* from the Ludlow formation of Great Britain. The description, which was not very detailed, appeared in Decade i, British Organic Remains, Memoirs of the Geological Survey of Great Britain, 1849. The type specimen possessed a circular disc covered with squamiform plates, and five arms "formed of alternating ossicula." Genital openings are said to occur in the angles of junction of the arms beneath. The next reference to *Protaster* is in the Annals and Magazine of Natural History for November, 1857. Two new species, *P. miltoni* and *P. leptosoma*, are described by Mr. J. W. Salter. The genus is more thoroughly defined, but, unfortunately for future workers, it is made to include forms with the ossicles opposite as well as those in which the arrangement of these elements is alternating. In this article Mr. Salter ascribes to this genus a form, *P. salteri*, described in the Quarterly Journal of the Geological Society for 1845, as *Ophiura salteri* by Sowerby. The genus *Tæniaster* was established by Billings in 1858, with two species, *T. spinosus* and *T. cylindricus* from the Trenton of Ontario. As this genus has been thought to be identical with *Protaster* it must receive consideration here. (Decade iii, Canadian Organic Remains, Geol. Sur. Canada). In the third volume of the Palaeontology of New York, which appeared in 1861, Professor James Hall describes a

form from the Lower Helderberg as *P. forbesi.* The same year Hall describes *Onychaster (Protaster) barrisi* in "New Crinoidea from the Burlington group." The same author revises his description of *P. forbesi* in the 20th Report of the Regents of the State of New York, 1868. With regard to the shape of the ambulacral plates he says "The ambulacral plates are obliquely quadrangular and alternating to a slight degree. The pores are comparatively large, truncating the outer adjacent angles of the ambulacral plates." The figures of this species in Vol. iii of the Palæontology of New York were based on a misconception, which the author has corrected in the article cited above. Making allowance for this emendation, the ossicles may be said to alternate and to possess a "boot-shaped" inferior aspect. *Tæniaster* of Billings is also reviewed by Professor Hall, who thinks a disc can be discerned in the type specimen of *T. spinosus* and adds "The structure of the ray is precisely of the same character as the ray of that species which I have named *Protaster forbesi.*" With regard to *T. cylindricus* he says "The structure of the rays is very similar to that of *Protaster.*" In 1869 Meek and Worthen describe *Protaster gregarius* in the twenty-first volume of the Proceedings of the Academy of Natural Sciences of Philadelphia. In Vol. i of the Geological Survey of Ohio, in the year 1873, F. B. Meek describes *Protaster granuliferus* from the Cincinnati group of Moore's Hill, Indiana. The disc of this species is covered with an integument filled with a vast number of minute grains of calcite. The ambulacral ossicles alternate, are rectangular at their inner ends and the outer anterior margin of each is largely excavated so as to form a large pore. It is stated that this species was referred to as *Alepidaster* in the American Journal of Science for 1872: the reference can not be found.

Miller and Dyer describe and figure *P. flexuosus* from the Cincinnati formation in the first volume of the Journal of the Cincinnati Society of Natural History, 1879. It would appear that the specimens are too imperfect ventrally, to allow a satisfactory description of the ossicles to be made. In the same volume E. O. Ulrich establishes the genus *Protasterina* with one species *P. fimbriata.* It would appear that the ambulacral ossicles are hour-glass shaped. Later reviewers have considered this species identical with *Protaster flexuosus* of Miller and Dyer.

In the Memoirs of the Geological Survey of Great Britain, Vol. iii, 1881, Dr. A. C. Ramsay re-describes *P. salteri.* This species is founded on a single specimen which seems to have had a varied ex-

perience. It was first referred to as *Ophiura* by Forbes and Sowerby and then lost; on being regained, it formed the material for Ramsay's description, the essentials of which are the absence of a disc and the fact that the ambulacral ossicles alternate and are triangular in shape. It is also interesting to note that Professor Ramsay is inclined to place the form under the genus *Tæniaster* of Billings.

In the fifth volume of the Journal of the Cincinnati Society of Natural History for the year 1882, from the pen of S. A. Miller, appeared the description of *Tæniaster elegans* from the upper part of the Hudson River formation at Waynesville, Ohio. This species has no disc, according to the author. The ossicles are most distinctly alternate in position and decidedly boot-shaped in their inferior aspect. Were it not for the absence of the disc one would not hesitate to call it a typical *Protaster*. Another form is described in the same volume as *Protaster miamiensis*; it is from the same horizon. A disc is present but the ossicles are subquadrangular on the ventral side.

In his Monograph on British Fossil Echimoderms, Dr. Thomas Wright refers to *Protaster miltoni*, Salter, *P. leptosoma*, Salter, and *P. salteri*, Forbes (Sowerby) also to *Tæniaster* of Billings. This author ascribes all the *Protasters* to the *Asteridæ* on account of the discovery of a madreporite.

Protaster daoulasensis is described by Davy in the Bulletins of the Geological Survey of France, Series iii, Vol. xiv, also a species by Dewalque, the reference to which has not been ascertained.

An important contribution to the literature of the Fossil Ophiurians was contributed to Palæontographica and appeared in Vol. xxxii for the years 1885-1886. The author, Dr. B. Stürtz, attempts a revision of the various forms and presents a system of classification, the essentials of which are as follows: Group I – Protophiureæ—Ambulacral ossicles opposite. Most forms have a dorsal rosette of radial plates on the disc. Dorsal integument of the arms is variable. The species included are *Protaster miltoni* and *P. leptosoma* also a new genus and species, *Furcaster palæozoicus*.

Group II.—Ophio-encrinasteriæ—The dorsal rosette is present, the ambulacral ossicles are alternate, there is a double row of spine bearing side plates and the oral apparatus is derived from these latter plates The species included are *Protaster forbesi*, both of Billings' species of

Tæniaster, *Eugaster* and *Ptilonaster* of Hall and a new genus *Bundenbachia*.

Still another *Protaster* is described by Dr. J. W. Gregory in Vol. iii of the Geological Magazine for 1889. This form, *P. brisingoides* is particularly interesting as it is from the Lower Silurian of Victoria, Australia.

In Vol. xxxvi of Palæontographica Dr. Stürtz makes the Ophioencrinasteriæ include *Tæniaster*, Bill, *Eugaster*, Hall, *Palæophiura*, Stürtz, *Bundenbachia*, Stürtz, *Protaster*, Forbes, *Protaster*, Billings, *Protaster*, Hall, and *Protaster*, Gregory. He makes the significant statement that all these *Protasters* are different genera bearing the same name. To his other group, Palæamphiuridæ (Protophiureæ) he removes *Protaster* div. sp. Salter.

In the later of these works, Dr Stürtz has defined the genus *Protaster*, and he has placed in separate groups different species formerly referred to that genus.

A re-examination and description of Forbes' type had become necessary; this was done by Dr. J. W. Gregory, and his results appear in a modern classification of the Palæozoic Ophiuroidea in the Proceedings of the Zoological Society of London for the year 1896. An outline of this classification, as far as forms previously ascribed to *Protaster* is concerned, follows :

Order. LYSOPHIURÆ.

Ophiuroidea of which the ambulacral ossicles are alternate and are not united into vertebral ossicles. There are no ventral arm plates, and the under side of the arm is occupied by an ambulacral furrow.

Family I. Protasteridæ.

Lysophiuræ which have *boot-shaped* ambulacral ossicles. Each of them consists of a "body" lying beside the middle line of the arm, and of a lateral "wing" projecting transversely from the body of the ossicle.
Genus I. Protaster, *Forbes.*
Synonyms;

Protaster, Hall.

Protaster pars of Salter, Miller, Billings, Gregory, Stürtz.

Non *Protaster* of Meek and Worthen, Dewalque, Davy.

Protasteridæ with a well-marked disc; long, tapering, very flexible arms. Some of the ambulacral ossicles are Y-shaped. Scales of the disc fairly large.

The following species are mentioned by Gregory: *P. sedgwicki*, Forbes, *P. forbesi*, Hall and *P. biforis*, Gregory, a new species.

Genus II. Bundenbachia, *Stürtz.*

Disc soft and delicate; covering plates apparently small and thin. Ambulacral ossicles with a dumbbell-shaped body and thin tapering wing. . . . . *Bundenbachia* differs from *Protaster* by the irregular nature and soft plating of the disc, by the presence of spine bearing plates attached to the adambulacral ossicles, and by the different form of the ambulacral ossicles.

Family II. Palæophiuridæ.

Lysophiurae, in which the ambulacral ossicles are long and bar-shaped with the longer axis parallel to the arm. The ossicles are never *boot-shaped.*

Five genera are established. The forms previously described as *Protaster* are as follows:

Protaster brisingoides, Greg, becomes type of new genus *Stürtzura*. *Protaster leptosoma*, Salter, becomes *Stürtzura leptosoma.* Also *Tæniaster cylindricus*, Billings becomes the type of a new genus, *Tæniura Eugaster*, Hall, and *Ptilonaster*, Hall are included.

Order II. STREPTOPHIURÆ, *Bell.*

Ophiuroida, in which the ambulacral ossicles are opposite. . . . *Protaster miltoni*, Salter, becomes the type of a new genus, *Lapworthura*. *Protaster daoulasensis*, Davy, becomes *Furcaster daoulasensis. Protaster gregarius*, Meek and Worthen, becomes *Aganaster gregarius.*

Of all the species of Protaster there still remain the following:

Protaster salteri, Sowerby (Forbes). This species must be removed from the genus as now defined, because the ossicles are described as triangular.

Protaster flexuosus, Miller and Dyer, cannot be retained as no information as to the shape of the ossicles ventrally was determinable from the type specimens.

Protasterina fimbriata, Ulrich, has hour-glass shaped ossicles, and must therefore be dismissed.

Protaster granuliferus, Meek. This species may be retained as the ossicles are said to be "longer transversely than in the direction of the length of the arms; each largely excavated at its outer anterior end, so as to form a large pore or pore-like depression, and divided transversely by a furrow into two parts." It is evident that this excavation of the ossicle would give it a boot-shaped appearance.

Protaster miamiensis, Miller, must be removed as the ossicles are described as subquadrangular.

Tæniaster elegans, Miller. From the description and figure this form would seem to be a true *Protaster* but for the fact that no disc is present. From the great similarity to the form about to be described, it seems to the writer that a disc had been present in Miller's species but was lost.

There can be no doubt that the form and arrangement of the ambulacral ossicles forms the best basis of classification for the Palæozoic Ophiuroida. It is very doubtful, however, if a true conception of this form can be arrived at by an inspection of the ventral aspect alone. From subquadrate to boot-shaped ossicles all sorts of intermediate shapes are obtained, depending on the degree to which the pore has encroached on the outer anterior angle of the original subquadrate body. In the species about to be described the "toe" of the boot is much shorter than in the genotype and the dorsal aspect reveals the ossicles with an entirely different appearance. In order to arrive at a true conception of the shape of these bodies, sections were made across the arm. The result of this investigation was so important that it has resulted in the extension of this article beyond the mere description of the species as was first intended.

PROTASTER WHITEAVESIANUS, *sp. nov.*

The species is founded on four specimens, one showing the dorsal and three the ventral aspect. There are five tapering arms and a well marked disc. The size of all the specimens is approximately the same, but the one exposing the dorsal surface is alone perfect enough to afford

accurate measurements of the extent of the organism. As the disc is not preserved in this specimen its dimensions are taken from the other examples. The extreme width along the most extended arms is 60 mm. The diameter of the disc is 15 mm. and this structure is distinctly circular in outline. At their proximal ends the arms have a diameter of $2\frac{1}{2}$ mm., and at their maximum width, about half way down their axis, the diameter is slightly more than 4 mm. The dorsal integument of the disc is unknown. The ventral side was covered by plates or large scales. The preservation is not sufficiently perfect to justify a distinct statement in this respect, nevertheless the weight of evidence points to a mosaic of thin, sub-hexagonal, minutely tuberculated plates. (Fig. 1).

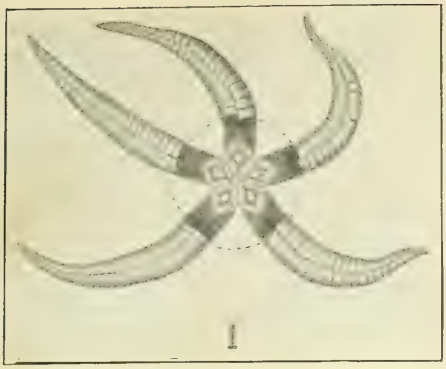
The ventral side of the arm shows four rows of plates. The two inner rows are the ambulacral ossicles; they are distinctly boot-shaped and strictly alternating. The two rows are separated by a deep and wide ambulacral furrow. The body of each ossicle is about one mm. long and the wing is somewhat shorter; they are separated from each other by a round interspace which indents the distal border of one ossicle and the proximal margin of the one next succeeding. Along the length of each ossicle is a slight depression, probably for the attachment of muscles.

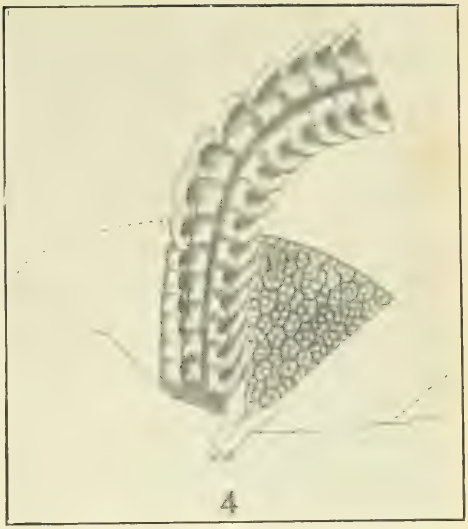
Each plate of the outer rows shows considerable evidence of being composed of two separate calcifications. The line of suture is very indistinct in all cases, and in most of the plates it is not to be discerned at all. Abutting against the "toe" of the "boot" is a stout rounded bar which passes outwards and then forwards in a long curve to the outer distal margin of the segment. These are the adambulacral plates and they bound the ambulacral pore on the outside. Firmly attached to the outer margin of this plate is the side plate, which arches inwards ventrally so as to protect the soft parts of the arm. While terminating in a sharp edge ventrally the dorsal margin is blunt and of nearly the same diameter as the plate itself. The plate is ornamented externally by two thickened ridges of which the anterior is more pronounced, and there is no evidence that it bore spines. These side plates overlap distally, and there is some variation in their shape in different parts of the arm. Figures 2 and 4 show the relation of the ventral arm plates. The proximal left hand side of the arm shown in the latter figure exhibits the side plates in perfect condition; distally it is more and more worn down so that the ventral edges of the side plates are removed and

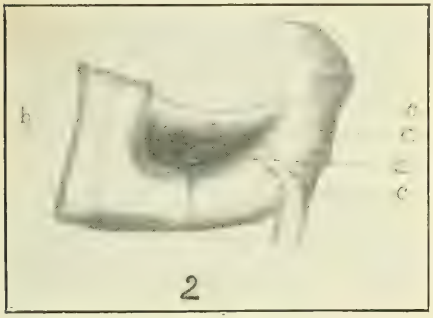
the adambulacral ossicles are exposed. The plates of the right hand side are even more reduced by weathering.

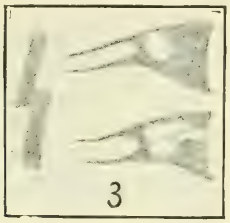
The dorsal side of the arm was protected by two rows of very thin plates, placed directly over the ambulacral ossicles. They are oblong in shape and curve outwards to meet the side plates. Owing to their extreme thinness and to the fact that they are firmly attached to the ambulacral ossicles by secondary calcification, their detection was a matter of some difficulty. That they exist as separate elements is proved by the discovery, in a thin section, of a distinct suture between them ; that they are not really part of the ossicle is proved by their different microscopic appearance. I am not prepared to state that these dorsal plates were originally calcareous ; their microscopic examination shows a different aspect from the other parts, and the calcite of which they are now composed is evidently secondary. This point is of importance in view of the fact that Dr. Stürtz is of the opinion that many of these ancient forms were destitute of a dorsal system of shields on the arms. The dorsal aspect of the ambulacral ossicles is very different from the ventral. Along the mesial line they present a slightly concave inner edge ; as they are strictly alternate, the two adjacent angles of a contiguous pair on one side fit into the concavity of the one opposite. Passing outwards the anterior and posterior margins converge and curve forward to the distal border of the side plate. At the extremity, the ossicles are deeply notched so as to present a forked appearance. Each prong of the fork is no thicker than a hair at its end. The inner portion of the ossicle is extended downwards to form the main part of the ossicle as viewed ventrally ; the "toe" of the "boot" is a ventral expansion connected with the posterior prong of the fork, which continues outward along the distal margin of the adambulacral plate. The anterior prong borders the ambulacral pore distally. Figure 3 shows a section across two ossicles. The round opening is the ambulacral pore, which seems to pass through the ossicle to make connection with the ambulacral groove. Figure 6 shows the dorsal aspect of an arm. The cover plates are closely attached to the ambulacral ossicles ; distally they are almost intact, but proximally they are much worn away exposing the two wing-like extensions of the ossicles.

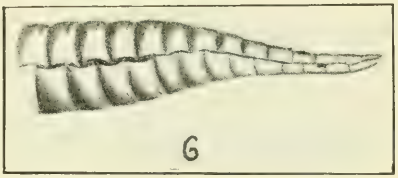
The dorsal side of the disc shows an elegant pentagonal rosette, composed of twenty plates (Figure 1). Ten of these plates radiate from the centre in pairs and occupy the interradial positions ; they are probably analogous with the dorsal shields of better known forms. From the











PROTASTER WHITEAVESIANUS, SP. NOV.

FIGURE 1.—Dorsal aspect. The dorsal arm plates and the ambulacral ossicles are removed within the area of disc. Natural size.

FIGURE 2.—Ventral posterior view of segment. X 20. (a) Side Plate. (b) Ambulacral ossicle. (c) Adambulacral ossicle. (d) Position of dorsal posterior wing of the ambulacral ossicle. (e) Dorsal anterior wing of ambulacral ossicle.

FIGURE 3.—Section across two adjacent segments slightly beneath the dorsal surface. X 12.

FIGURE 4.—Ventral view of part of arm and disc. The outer and right hand portion of arm is much worn down. X 4.

FIGURE 5.—Side view of proximal ambulacrals and the outer plate of dorsal rosette. The dorsal wings of the ambulacral plates are removed. X 12.

FIGURE 6.—Dorsal view of the extremity of an arm. Distally the covering plates are intact. Proximally they are more and more worn away. X 4.

outer ends of these plates, the ten others converge in pairs to the centre of each ray ; these may be analogous to the forked wings of the proximal ambulacral plates. Figure 5 shows the three first ossicles of one side with the wings worn away, and exhibits the manner in which the outer rosette plates abut against the first ambulacral ossicle.

Little is known of the oral apparatus. The syngnaths are formed from the adambulacral plates. They consist of stout curved rods projecting inwards and curving upwards at their inner ends. (Fig. 4.)

The present species differs from the genotype, as figured by Gregory, in that the ambulacral ossicles are not crossed by a transverse groove on their ventral surface, and by the shorter length of the "toe" of the "boot." The ossicles are very like those of *Protaster biforis*, Gregory, but the adambulacral ossicles and side plates are very different ; in this latter respect the form approaches *Bundenbachia*, Stürtz. The arrangement and shape of both sets of ossicles are much like those of *Lapworthura miltoni*, Salter, sp., except for the fact that in this species the ossicles are opposite and not alternate. From *P. forbesi*, Hall, it differs in the greater size, the strict alternation of the ossicles and the absence of spines. The most striking similarity was observed with respect to *Tæniaster elegans*, S. A. Miller. While this form is only half the size of the present species and from a much higher formation (the top of the Hudson River), there is nevertheless a close resemblance in the shape and arrangement of the ossicles. *T. elegans* is, however, spinous, and lacks a disc, according to its author, who had over thirty specimens to examine. It is doubtful if the original absence of a disc can be confirmed in a species so strikingly like the one under review.

Dr. Whiteaves has kindly allowed me to examine the types of *Tæniaster cylindricus*, Billings. In one only of these specimens can the shape and arrangement of the ambulacral ossicles be seen, and then only very indistinctly. They appear to have an inferior aspect, approximating to boot-shaped, and they are almost uniformly opposite. I should be inclined to place this specimen under *Lapworthura* of Gregory. In establishing the genus *Tæniura* for the reception of *Tæniaster cylindricus*, Dr. Gregory states that the ambulacral ossicles are "rods lying parallel to the arms." It is apparent, therefore, that he based his description on different specimens from the one now in my hands. In any event, the new species is distinct, for it is more than twice as large, the ossicles

alternate strictly, the disc is well-marked, and the arms are much less ribbon-like in character.

If I am right in ascribing this form to *Protaster*, it is the largest as well as the oldest representative of that genus yet discovered.

I have pleasure in naming this species for the distinguished palæontologist of the Geological Survey of Canada, Dr. J. F. Whiteaves.

Type Specimens No. 638 T. University of Toronto Museum.

Formation Trenton.

Locality Kirkfield, Ont.

Collector Mr. Joseph Townsend.

THE GEOLOGICAL CONNEXIONS OF THE CARIBEAN REGION.

BY R. J. LECHMERE GUPPY.

(Read 30th January, 1909).

The Hypothesis (commonly called the Atlantis Theory) that a portion of the area now covered by the Atlantic Ocean was once land, occupied my attention in 1865. I was at that time engaged in the study of the West Indian Tertiary Fossils, for which facilities were afforded to me by my kind friend, Dr. Woodward, F.R.S., Head of the Geological Department of the British Museum. In my papers read to the Geological Society of London, 21st February, 1866, and 20th June, 1866, and published in the Journal of the Society, Vol. XXII, pages 281 and 570, I stated the results to which my investigations had led me ; and in the later papers published in the Geological Magazine, 1867, page 496, and 1874, page 404, I gave some further observations with a brief summary of the results so far. Since that time many workers have contributed to the Geology and Paleontology of the West Indian Area. A list containing mention of most of the works published is appended to a paper by me in the Transactions of the Canadian Institute, 1904-5, page 137. Those which have special reference to the earth-movements in the Caribean Region are by Spencer (on Cuba, Geol. Soc. Amer., Vol. VII, 1895 ; Antillean Continent, Idem, 1895 ; Antillean Valleys, Trans. Can. Ins., Vol. V, 1895 ; Changes of Level Mexico, &c., Geol. Soc. Amer., 1897 ; Changes of Level Jamaica, &c., Trans. Can. Inst., 1898 ; and Development of Antilles, Journ. Geol. Soc., Lond., Vol. LXVII, 1901 ; also Windward Islands, Trans. Can. Inst , 1902) ; and by Hill (on Cuba, Bull. Mus. Harvard, Vol. XVI, 1895 ; and Jamaica, Bull. Mus. Cambr., Vol. XXXIV, 1899). But these writings, though valuable in their way, do not seem to have probed the question at all, and have scarcely assisted us to any real solution of the problems presented by the present and past distribution of life and of land and water in the region under notice.

It is not my intention to go over ground that has already been worked, and my present efforts are not intended as a complete statement of the case, but merely a contribution to its further development. But a brief reference to some of the most important observations may be convenient. Some works have probably never come to my notice, and

there are others, which though known to me, are not now available to me for reference.

The ancient idea of a mass of land occupying a portion of the site of the Atlantic is derived from a solar myth, which is stated to have come from Egypt. This origin is admitted by Henry Davis, the Translator of Plato, who quotes Martin, "Etudes sur le Timée de Platon." From whence the Egyptians obtained this and some other myths we have no means of ascertaining; and their characteristics seem to render it unlikely that they originated in Egypt. (See Cox, Aryan Mythology, 2nd Ed., page 248. This subject has not been worked out by Cox, who seems to have avoided Egyptian Mythology.) From any point on the eastern shores of the Western Ocean where a clear view over the sea can be obtained, the Atlantis may often be seen in the evening when the sun nears its setting. From the Atlantic Ocean I have frequently seen it, with every circumstance of mountains, capes, bays, &c.

But what we have to deal with here is not mythical but real land, which is supposed to have formerly occupied space now covered by the ocean.

To the botanical Researches of Heer is due the first attempt to place the Atlantis Hypothesis on a basis of fact. His work is referred to in my papers in the Journal of the Geological Society of London, Vol. XXII, page 583 and Geological Magazine, 1867, page 497. So far the best summary of the question is to be found in Lyell's Elements of Geology, sixth edition, page 265. I have in my possession a paper in Spanish which seems to be of a date anterior to Lyell's work. This contains a list stated to be complete of all the writings on the subject, ten in number, no one of which is subsequent to 1860. This work is entitled "La sumergida Isla de Atlantis," and in it the arguments for the existence of an atlantic land are summed up. The paper was forwarded to me by the author, but as no name, place or date is mentioned on it, its origin has escaped me in the lapse of years.

It has been suggested that a connexion existed between Europe and America by way of Greenland, Iceland and the Hebrides. And a very strong support has been given to this suggestion by zoologists and botanists. Newbery says (Later Extinct Floras: Ann. Lyc. N.H., New York, 1868, page 37) that the eocene tropical or subtropical flora of Europe was crowded off the stage by the temperate flora of the miocene which, accompanying a depression of temperature, had migrated from

UNITED STATES
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
ALABAMA
MISSISSIPPI
LOUISIANA
TEXAS
FLORIDA
CUBA
YUCATAN
MEXICO
GUATEMALA
HONDURAS
NICARAGUA
COSTA RICA
PACIFIC
CARIBBEAN GULF
VENEZUELA
COLUMBIA
GALAPAGOS
SOUTH AMERICA
Barbados
Tobago
Trinidad
Martinique
Guadeloupe
Virgin Is.
Porto Rico
Haiti
Jamaica
Caracas
Maracaibo
Orinoco
Essequibo
Demerara
Berbice
British Guiana
Dutch Guiana
French Guiana
Surinam
Amazon
Para
Rio Grande
Mississippi River
Ohio River
Washington
Richmond
Savannah
Baltimore
Chesapeake
EXPLANATION
Principal Lines of Dislocation
Atlantis Land
Calapagia and other ancient Land
Amazonian Sea

America while the eocene flora retreated South and East, and is now represented by the living indo-australian flora. In dealing with these questions these facts must ever be borne in mind ; but whatever may be the case as regards the connexion referred to, it in no way invalidates the evidence for a more southerly connexion between North Africa and South America. The Flora and the Fauna of North America and those of the Caribean Region are so distinct and have so few elements in common that we cannot suppose any extensive migration between them, while the alliances between the Faunas of North Africa and South America are clear and unmistakable.

The contributions of S. P. Woodward to the question should not be overlooked. In his "Manual of Mollusca" (1856, page 403), he says "the presence of several species of the old-world Genera, Clausilia and Streptaxis, both wanting in North America, becomes a significant fact when taken in connexion with the affinities of the higher animals of South America and Africa. These imply a landway across the Atlantic at some very remote period more direct than would be afforded by the Continent which is believed to have united the boreal regions at the close of the miocene age." Further he refers (page 404) to the resemblance between certain land shells found in the Eocene of Europe to living shells of South America. Subsequent writers have also dealt with this subject.

Bland (Ann. Lyc. N.H., New York, 1869, page 241) notices the observation of Julien (Ann. Lyc., N.H., New York, 1866, page 251) that Tortoises occur at Sombrero allied to those of the Galapagos. And in the same place will be found a remark of Cope's that the discovery in Anguila of a large extinct Rodent indicates that the Caribean Continent had not been submerged prior to the close of the post-pliocene, while a wide strait separated it from the shores of North America. If our present views are correct this Caribean Continent must have been the Atlantis ; for the Caribean Sea instead of being a Continent was a Gulf of the Pacific, And the inference as to the separation of this Atlantis from North America is no doubt correct ; but the date of the submergence is more doubtful.

Andrews (Descriptive Catalog of the Tertiary Vertebrata of the Fayum, 1906) is inclined to regard the evidence as lending additional support to the theory that in mesozoic times Africa and South America were connected by land, and that "the final separation of the two continents did not take place until eocene times."

It appears certain, therefore, that the ancient distribution of land including (1) the free waterway between the Caribean Sea and the Pacific Ocean ; and (2) the Atlantis Land, was not specially tertiary, but came to an end in the tertiary period, having probably endured since the jurasic period, though it is probable that the limits of Jules Marcou's hypothetical jurasic continent (Marcou, Roches du Jura, 1860), should not have included Central America, which, with the Caribean Sea, were probably under water at that time, whilst the land extended from the East of the Antilles to North Africa. (See Journ. Geol. Soc., Lond., Vol. XXII, 1866, page 589, and Geol. Mag., Lond., 1867, page 497).

What further evidence may be derived from the invertebrate fossils of Trinidad and Jamaica will be briefly indicated in the succeeding portion of this paper. The evidence drawn from the distribution of vertebrate animals seems to have lent some further and very important light to the discussion of the subject, as just noticed in the case of the egyptian fossil vertebrates. But the distribution of living reptiles has enabled Hans Gadow to furnish a nearer approximation to the probable arrangement of Central-American land than any yet presented According to his diagrams (Proc. Zool. Soc., Lond., 1905, II., page 235) Central America and Panama were under water until the end of the eocene period and rose into land during the miocene, being then united to Cuba, Haiti and Jamaica. The latter islands had been partly or wholly submerged until that time. They doubtless formed part of the margins of the Atlantic Land, which is thus shown to have lain to the eastward and northward of the Caribean Sea.

The work of Messrs. Jukes-Browne and Harrison on Barbados was a notable addition to our knowledge of the geology of the West Indies, and especially of the oceanic deposits. Speaking of the latter they say : " Radiolarian ooze does not exist in the Atlantic, but is found in the Pacific and Indian Oceans at depths of from 2,000 to 3,000 fathoms. Its existence in Barbados, therefore, suggests the idea that it was formed in a deep basin, which was open to the Pacific . . . . and consequently at a time when the Isthmus of Panama did not exist." (Report on Geology of Barbados, 1890, and Journ. Geol. Soc., Lond., 1892, page 224.)

Gregory (in the Journal of the Geological Society of London, 1895, page 296 and seq.) has contributed some very pertinent observations towards the solution of the question. I propose in some respects to follow his method in this paper, that is to say, I shall deal with some

paleontological facts and considerations as supplementary to the main questions; and for this my purpose will resolve itself into two branches which I shall pursue as far as the evidence at my disposal goes, not repeating what has already been advanced in previous writings. These two points are—1. A communication by land between the Caribean Region and North Africa or South Europe. 2. A communication by sea between the Caribean Sea and the Pacific Ocean.

I find Gregory's own decision in close approximation to mine. He says—"All recent zoological work has tended to show that though at one time the Caribean Sea must have been in direct communication with the Pacific this was at a very distant period." (Journ. Geol. Soc., 1895, page 302). Then again (page 305) he says—"It is not at all certain that when the Isthmus of Panama was submerged there was a free communication between the Atlantic and Pacific Oceans. The Caribean Sea may then have been a gulf from the Pacific, separated from the Atlantic by the land area of the hypothetical Antillia." This conclusion of Gregory's is indeed exactly what the evidence I am now bringing forward seems to suggest. Only that instead of Antilia, I substitute Atlantis.

The arrangement of the lesser Antilles into two groups, an inner and an outer, was noted by Schomburgk (History of Barbados, page 532). It is well indicated in Cleve's geological map of the North-Eastern West India Islands (K. svenska Akad Handlingar Stockholm, 1871). The inner group is volcanic, the outer (consisting of Anegada Barbuda, Deseada and the eastern portion of Guadelupe) is calcareous and sedimentary. Schomburgk alludes to the opinion of Vonbuch relative to the connexion of this chain of islands with the mountain ranges of Caracas. The separation of these two groups of islands marks, I think, one of those great lines of dislocation which occur on the margin of the ancient Atlantic Land. It extends from Haiti in a wide curve to Caracas. I have prepared a map which will show better than any verbal description what I conceive to be the course of those dislocations which mark the outer line of the Pacifico-Caribean Gulf. On the Island of Haiti a line of dislocation extends from the Bay of Samana in the north-east to Bahia de Manzanilla near Monte Cristo in the north of the Island. This large depression called Lavega was under water in tertiary times, as is proved by the extensive development of miocene formations along its margins with an extremely rich and characteristic fauna of mollusks, corals and foraminifera. A parallel depression crosses the south-west portion of the same island shown by lakes, laguns and bays extending

from Bahia de Neiba to Sanmark Channel to the north of Gonave Island. These depressions are no doubt prolonged under water and extend to the east and south along the line of the Antilles, their supposed course being indicated on my map by broken lines. I suppose the line of depression I have indicated as crossing the north-eastern portion of the Island of Haiti to be a continuation of the dislocation which marks the separation of the two groups of the Antilles I have already mentioned.

A depression strongly resembling that just referred to in the Island of Haiti occurs in the northern part of Venezuela. One part of this depression is indicated by the Gulf of Cumana or Cariaco, and it probably extends on the east to the Gulf of Paria, where it joins or forms a continuation of the great dislocation indicated in my paper on the "Growth of Trinidad" (Trans. Can. Inst., 1905, page 137), which I have there shown, and also in my paper in the Geological Magazine (1900, page 322), to extend northward between the Islands of Tobago and Barbados on the east, and Grenada S. Vincent, &c., on the west; and thus in fact to be a continuation of the line of dislocation separating the inner group of the Antilles from the outer group, which line crosses the north-eastern part of Haiti as already stated. The area about Cumana (see Wall's Map of Venezuela, Journ. Geol. Soc., Lond., Vol. XVI, 1860, page 470) includes tertiary as well as cretaceous rocks. Many of the tertiary fossils from Cumana described by me in the Journal of the Geological Society of London (1866 Vol. XXII, page 579) are of the same species as those found at Lavega in Haiti, and the geological resemblance between the two localities is remarkable. I suppose this line of dislocation, which I have thus traced from Haiti through the north-eastern Antilles across Guadelupe and between Barbados and Tobago on one hand, and St. Vincent and Grenada on the other, to the Bocagrande and Gulf of Paria and thence to Cumana, extends westward to Caracas and possibly thence to the Lake of Valencia, which is situated in a part of the same depression.

There is, I think, a fair amount of evidence for the existence of the line of depression or dislocation I have described. But that for the inner line is less clear, and its course must be regarded as more hypothetical. This is owing to the supposed course being mostly under water with no indication above the sea level of its existence, which, therefore, is presumed from inference only. At the same time the beginning and end of the line are pretty obvious, the former being the depression described as existing in the south-western part of Haiti,

and the latter lying near the islands off the coast of Venezuela as indicated in the map. The soundings to the west of the line of the Antilles show a rapid descent into deep water, and so do those to the north of the "continental shelf" to the north of South America.

In my paper on the "Growth of Trinidad," I have indicated the principal dislocations which occur in this locality; and there is no difficulty in inferring from this the existence of similar disruptions on the neighboring continent. The lines of dislocation are seldom simple, but consist of several sub-parallel or radiating fissures especially developed at certain points, such as the Gulf of Paria, which points may be considered foci of disturbances. For instance, another line of depression appears to pass along the course of the Guarapiche River to the south of the Bergantin in the east of Venezuela, and this comes out on the coast between Nueva Barcelona and Unare. The upheaval of the southern part of Trinidad and the dislocations which separated that island from the South American Continent were certainly post-miocene; but they may have been in progress during a very long period of geological time. In the paper referred to I have shown that in cretaceous times the greater part of what is now Trinidad was sea, the northern ridge alone rising above the water; and that northern ridge itself was previously under water, being formed of materials probably derived from the north-eastward, while the materials of the southern part of the island were derived from the south-westward. Two conclusions seem to follow from this. First, that if such changes can occur on a comparatively small scale, as in this case, there is no impossibility about their occurring on a larger scale. And, second, that as there was land to the north-east of Trinidad at a very ancient date (precretaceous or jurasic at the least) while all to the south and south-west was then sea, it is probable that the Atlantis was a very ancient land which gradually dwindled away through all the later mesozoic periods down to and including part of the tertiaries.

In my paper on the "Growth of Trinidad" just referred to, I mentioned the fact that during the cretaceous and tertiary periods the whole of the area now drained by the Orinoco and the Amazons was sea. It is quite probable that this sea communicated with the Pacific by means of a strait or channel of which the Gulf of Guayaquil is a vestige. In our present inquiry the existence of the Unare Hiatus on the northern coast of Venezuela is of some importance, as it was probably through that strait that the Caribean Sea communicated with the sea that filled the Orinoco Valley and covered the southern part of Trinidad. Could

we confidently adopt the geology of Karsten (Geogn. Vehaltnisse des Westlichen Columbien, Wien, 1858), we should have no difficulty in finding a passage from the Caribean and Venezuelan region to the South Pacific, for he shows a continuous and extensive development of tertiary formations on the north side of the Orinoco via the plains of the Meta and the upper waters of the Amazons to the Gulf of Guayaquil, the higher portions of the northern part of South America being newer and older cretaceous. Some doubt, however, rests upon some of Karsten's delimitations, and besides, he marks as "plutonic" the region from Paria to Cumana, and the central portion of the Isthmus of Panama, whereas these are probably altered sedimentary rocks not comparable with the plutonic rocks of Guiana and Brazil. The difficulty is the height and extent of the Andes. It is true that in the neighbourhood of the Gulf of Guayaquil there is a break in the continuity of the great mass of the Andes. If, therefore, the Region marked by Karsten as tertiary and cretaceous was really occupied by sea during the cretaceous period and only gradually became land during the tertiary period, we have ample provision for a waterway fulfilling all requirements for the migration of organisms from the South Pacific to the Caribean Region.

THE OCEANIC ROCKS OF JAMAICA.

Though the geology of Jamaica has been largely treated of first by the Government Geological Surveyors (1869) and subsequently by Robert T. Hill (Bull. Mus. Harvard, 1899), there remains a very great deal to be done in the working out of details and in the elucidation of the relationships of the formations to each other. I do not think that any mere visitor could do what is required. A residence of many years and a thorough grasp of the various features is required; but unfortunately the dislike of scientific knowledge which underlies and characterizes public feeling in the West Indies, and is the result of slavery and superstition in spite of all pretences to the contrary, makes it unlikely that under present conditions any advance will be made. The whole aim of the dominant classes in the West Indies is directed to the discouragement of the general cultivation of science.

Unfortunately on my late visit to Jamaica I was crippled by my constant enemy, rheumatism, so that I failed to do any geological work. But, by the kind assistance of one or two friends, I was enabled to obtain some material of interest. I take the opportunity of observing that fault has been found with my supposed determinations of the

geological age of Jamaican and other formations, but on this I have to observe that there never was on my part any pretense of discriminating between different horizons, either in the case of Jamaica or of Haiti. I had no means of doing this. I merely described the fossils and called them miocene, because those who preceded me had done so. It is true that I stated that the beds in which Orbitoides and Nummulina occurred were supposed to be miocene, but I was led into this error by my predecessors. In the case of Trinidad, I had more or less limited opportunities of studying the formations and of defining the fossil fauna of each locality. This soon led me to perceive that among the West Indian strata previously lumped together under the common name of miocene there were older strata as shown by the organic remains. At first I timidly called some of these "lower miocene," so as not to depart too far from received views. But later on I perceived that this was too much of a compromise, and that probably the expression "cretaceo-eocene" might not be putting too great an antiquity on such rocks, for example, the lower beds (Sanfernando beds) of the Naparima series in Trinidad.

Gregory (Journ. Geol. Soc. Lond., 1895, page 298) says it is advisable to correlate the whole of the beds in Barbados below the oceanic series with the Sanfernando or Naparima marls of Trinidad. These he says are generally assigned to the oligocene, as, for example, by Heilprin. The fossil molluskan and echinoderm faunas of Naparima and Manzanilla in Trinidad are entirely different to and of an older type than those of the Caroni beds in Trinidad, which are the equivalents of the Haitian and Jamaican faunas which have been called oligocene. I cannot admit that the name oligocene is wanted in the nomenclature of West Indian geology. For our present use the expressions pliocene, miocene and eocene are sufficient. They indicate the three great divisions of the West Indian tertiaries which are represented in different portions of the Caribean area, and each of which with some common species has a characteristic and distinctive fauna. The Scotland beds of Barbados may very likely go with the eocene of Naparima and S. Barts. It is necessary, I think, to make this conclusion clear, as there seems to have been some misapprehension on the point. I do not shut my eyes to the fact that there are some remarkable differences between the miocene faunas of Jamaica and Haiti, but on the whole the resemblance is very strong and can only be satisfied by placing them under the same geological head of miocene, while the strata I have indicated as eocene must be kept distinct and not confounded under the name of oligocene

with the miocene deposits. Understanding by the Sanfernando beds, the lowest beds of the Naparima series, we find the alliances strongly cretaceous, as shown by the brachiopoda, echinoderms and orbitoides (see Proc. Vict. Inst. Trin., 1897, page 169). Hill regards certain beds in Jamaica as eocene. These are the Cobre, Moneague and Montpelier formations, and I have little doubt that in this he is correct. But my acquaintance with the fauna of those beds does not enable me to pronounce a decided opinion. Deposits called post-pliocene or pleistocene exist in various parts of the West Indies, but the aspect of their faunas is entirely modern, and the characteristic species of the miocene are absent from them. The Caribean miocene fauna is unmistakably different from those of the periods following it, and though there may be a few species in common, the expert will scarcely fail in distinguishing between the formations belonging to each epoch. Thus, for instance, the barbadian fossil fauna, of which a list is given by Schomburgk (Hist. Barbados, page 562) is certainly pliocene or more recent, and that given by Gregory, as furnished by E. A. Smith, is of a similar geological date, though I could not accept the cabinet-naturalist names of many of the species, nor can I agree to the distribution there given, which is made out merely by taking closely allied and representative species and regarding them as identical. But I have no space here to deal with such questions, and must refer to my paper on the Molluska of the Gulf of Paria (Proc. Vict. Inst., Trinidad, 1894, pages 119 and 141) and elsewhere. All I would here remark is that naturalists who can make out of one type of radiolarian about twenty genera and a hundred species,* and a dozen or twenty species out of one species of Adeorbis or Risoina or Amnicola, while they cannot see that *Asaphis deflorata* of the West Indies and *A. rugosa* of the Pacific are distinct, can scarcely appreciate the kind of evidence we have to offer on the subject of the connexion and separation of ancient continents and oceans. The practical effect of the inability to distinguish valid species is shown in the case of the determination of a formation in Tobago as pleistocene on account of the occurrence in it of a species of ark said to be determined by authority as *A. grandis*, a recent Pacific shell, the shell in question being *Arca patricia*, a species well known to us as a characteristic miocene species not now living in the West Indies.

On my visit to Vere, in Jamaica, I found the rocks very much as described by Hill. The yellow limestone of Maypen is generally full of

*For example, Ehrenberg's Nasselaria, which probably represents only one real species, is made into about twenty-five genera and 180 species, and so with his other divisions. And Hakel has invented another lot of names on top of these. And, as he truly says, anyone who chooses to work at the subject could greatly increase the number of forms.

irrecognizable casts of molluska and other fossils. In one bed near Hillside I found *Polystomela craticulata.* This bed contains many subangular grains of quartz, and I found a small piece of pumice also. My friend, Mr. Earland, says of the foraminifer: "This is *Polystomela craticulata* without doubt. It is a very variable species, but always easily recognizable. The specimens are of the thick subglobular variety and closely resemble those from Perim." Brady (Chal. Rep., page 739) remarks that *P. craticulata* inhabits the shallow water of tropical and subtropical seas and ranges southwards from the Levant to the shores of Australia. It is not known in the Atlantic nor as a fossil species. Its presence as a fossil in the miocene strata of Jamaica is therefore comparable with that of *Planorbulina larvata* and *Pulvinulina favus* in Trinidad.

The yellow limestone with casts of molluska is obviously a distinct formation from the white limestone with foraminifera and radiolaria. This is again divisible into two, one which might be called a globigerina rock and the other of a more chalky texture, a radiolarian rock. The yellow limestone was probably formed in water up to and about one hundred fathoms in depth, while the true white limestones are deep sea deposits. The radiolarian rock is extensively developed in the neighbourhood of Buff Bay on the north coast of Jamaica. It is a white material, not unlike the English chalk, and of nearly the same colour and consistence. It is composed almost entirely of globigerina and radiolaria. A similar limestone to this white chalk occurs in Cuba, as described by Hill (Bull. Mus. Harvard, 1895, page 253). Here it underlies the yellow limestone, similar to that identified by Dall as miocene in Jamaica.

According to Tipenhauer (quoted by Hill, Geology of Jamaica, page 181) a similar rock occurs also in Haiti (see Journ. Geol. Soc., Lond., 1892, page 219).

Near Buff Bay (Orange Bay) in Jamaica, I found two very interesting deposits, but I failed to make out their relationships to the radiolarian rock. The first of these I have termed orbulina rock. This does not seem to be a separate formation, but a local and subordinate part of the oceanic series. After washing off the finer particles a sample of this rock gave about 60 per cent. of Orbulina and about 30 per cent. of Globigerina. Among the remainder I detected the following foraminifera in addition to Globigerina and Orbulina

Sagrina (virgula, &c.).
Polymorphina.
Nodosaria (arundinea, &c.).
Cristelaria.
Biloculina depressa.
Pulvinulina menardi.
Rotalia soldanii.
Truncatulina culter.
Stilostomela rugosa.
Ellipsoidina subnodosa.
Gaudryina pupoides.
Clavulina.
Pleurostomela.
Planispirina celata,

and a couple of ostracods.

Mr. Earland remarks of this orbulina rock: "It is evidently a deep sea ooze, a true globigerina ooze, and judging from the nature and condition of the shells, one laid down rapidly in tropical water of a depth of about 1,000–1,500 fathoms." In another place Mr. Earland remarks, "I have never seen any deposit containing such a high proportion of this species (orbulina)." Brady at page 611 of his "Challenger" Report remarks that at certain points in the Atlantic orbulinae occur in enormous numbers. The depths were 725 and 862 fathoms.

The second of these deposits was a pteropod marl, possibly a continuation of that at Portantonio, which is only a few miles distant, and of which an account is given in the Geological Report on Jamaica, pages 67 and 313. After washing off the argillaceous and fine particles the residue is remarkable for the quantity of volcanic fragments and for the molluskan and foraminiferal fossils, which, though very brittle, are in a fine state of preservation. Unfortunately of this and the orbulina rock I only obtained small samples, not being aware when collecting them of the nature of the contents. From the Portantonio pteropod marl thirteen species of foraminifera were named in the geological report. From the Orange Bay sample I obtained the following:

Miliolina seminulum.
Spiroloculina arenaria.
limbata.
Masilina alveoliniformis.
Biloculina depressa.
elongata v. serata.
comata.
Cornuspira foliacea.
involvens.
Peneroplis pertusus.
Frondicularia inæqualis.
Cristelaria aculeata.
Clavulina cylindrica.
parisiensis.
Bigenerina penatula.
Textularia aglutinans.
Textularia turis.
concava.
Bulimina pyrula.
inflata.
Casidulina crasa.
bradyi.
Nodosaria communis.
hispida.

cultrata.
italica.
Uvigerina pygmæa.
schwageri.
asperula.
Orbulina universa.
Globigerina buloides.
Lagena marginata.
Truncatulina culter.
Planorbulina ariminensis.
raphanus.
vertebralis.
consobrina
comata.
Pulvinulina menardi.
elegans.
Rotalia soldanii.
Amphistegina lesonii.
Ellipsoidina ellipsoides.

As the sample was only a small one it is probable that additional material would reveal a full set of foraminifera. This marl also contains molluska and polyzoa, a nucula being perhaps the most abundant mollusk.

The radiolarian rock. I now return to the white limestone or *radiolarian rock*, of which I have already given a brief account, and which has been referred to and described by previous writers on the Geology of Jamaica. The rock is difficult of disintegration, so I do not attempt to give a list of the foraminifera contained in it, but will merely say that they appear on the whole to be the same species as those found in the Oceanic Rocks of Barbados and Trinidad. Globigerina, as usual, greatly predominates. Of this rock Mr. Earland says: "The Jamaica chalk is unquestionably a deep sea deposit, but it would be hard to say at what depth it was laid down. Probably, however, no less than 1,200 —1,500 fathoms, judging from the sections I have cut. I did not succeed in disintegrating it sufficiently to work out the foraminifera, but I decalcified a small piece, and was struck with the abundance of the sponge remains." Gregory says of the corresponding Cuban deposits, "They proved to be typical pure oceanic oozes." My investigations led me to the conclusion that the spicules, which are very numerous, are not as I at first imagined the spicules of sponges, but the broken off spines of radiolaria. One specimen of a radiolarian that I found entire was similar to Ehrenberg's *Ceratospyris ateuchus* (Barbados Polycisten Mergel, 1875, Pl. XXI, F. 4) except that the long spines did not curve outwards but continued the original curve so as to form a figure resembling roughly in outline a crab like *corystes*, and having small spines along the exterior curve of the long spines which represent the claws of the crab. The body of this was 0.075 mm., while the entire length, including the spines, was 0·4 mm. Specimens like Ehrenberg's, plate XIII, Fig. I (*Podocyrtis princeps*) are common, and the long spiculae are only occa-

sionally found entire. Forms like Fig. 6 of Plate XXIV of Mrs. Bury's work are also numerous, and all these when broken up, as they generally are, furnish numerous spicules. As a rule these spines are much larger than and often several times the length of the diameter of the more or less spheroidal central skeleton of the radiolarian. The larger radiolaria are on account of their brittleness very difficult to secure entire, but I have managed to isolate a few with very long spines usually of the forms figured by Ehrenberg (Barbados Polycistenen Mergel, 1875, Taf. I). The largest radiolarian is like a miniature *Orbulina* with short spines protruding from it at rather distant intervals. Its size is about 0·4 mm. in diameter. It may be called *Halioma*, but those who like can have their choice of any of the numerous names given to this and similar forms with other generic epithets. Nearly all, perhaps quite all, of the jamaican forms are really identical with barbadian ones, but few are exactly alike, and there is a splendid opportunity here for anyone who wants to make species and genera to "create" a lot of them. For my part I consider them all referable to the species of which I give a list below, and to extend this list is like arranging the leaves of trees into genera and species. As Mivart truly remarks the forms of these organisms are not evolved by natural or sexual selection, nor indeed do I think those of foraminifera are so, though the species of foraminifera when worked out by an impartial and discriminating observer are as true and as fixed as any other species of animals. Some of them are extremely variable, but so are many animals and plants.

Gregory (l.c. page 295) has given a list of the radiolaria from the Cuban marls. As I am unable to appreciate the specific differences between these forms, I could not allege that they are the same as the Jamaican ones, but I presume they are, as they are identified with Barbadian forms.

List of the Jamaican Radiolaria.

Species 1. LITHOCAMPE Ehrenberg—Barbados Polycistenen Mergel, 1875, Taf. IV, Fig. 1-2.
A large number of Ehrenberg's genera and species belong to this specific type, including Lithornithium, and probably the whole of Eucyrtidina.

Species 2. DICTYOSPIRIS Ehrenberg. Ibid. Taf. XIX, Fig. 6-13.
With this goes probably the whole of the Spyridina. The development of the spines is mostly individual.

Species 3. PERICHLAMYDIUM Ehrenberg. Ibid. Taf. XXII, Fig. 12.
With this goes Calodictya generally.

Species 4. HALIOMA Ehrenberg. Ibid. Taf. XXVI, F. 1-3.
This probably carries the whole of the Haliomatina.
Actinolithus Ehrenberg. Ibid. Taf. I, Fig. 17-21
These are the broken-off spines of the radiolaria, of which immense numbers are found in the oceanic beds of Jamaica.

Notes on some of the fossil foraminifera of Trinidad as bearing on the Pacific connexions of the Caribean region. I have before noticed some singular facts in the distribution of the foraminifera of the oceanic beds of Trinidad (Geol. Mag., Lond., 1904, page 247). Among these is the absence of *Pulvinulina menardi* and Virgulina from these beds. It is true that in one of my lists I included the name of *Pulv. menardi*, but it was an error, and the specimen was really a small example of *Pulv. canariensis* from the radiolarian marl. *Pulv. menardi* and *Virgulina* are equally absent from the oceanic beds of Barbados, and it is singular that *Orbulina* is not recorded from the latter. Neither Orbulina nor Globigerina is included in previous lists from the pteropod marl of Jamaica, but I have found both with a large number of other foraminifera as shown in the list given above.

Planorbulina larvata (Chal. Rep. page 658, Pl. XCII, F. 5-6, Parker and Jones, Phil. Trans., 1865, Pl. XIX, F. 3). This is found abundantly in shallow water beds in Trinidad. Parker and Jones record it from "Indian Sea." Recent specimens supplied me by Mr. Earland came from Java Sea, 45 fathoms. According to the "Challenger" Report it occurs at seven stations in the South Pacific, 15–210 fathoms. It is also known from Honolulu and China Sea.

Pulvinulina favus Brady (Chal. Rep. Pl. CIV, F. 12-16). On the strength of one or two badly preserved specimens I included the name of this in my list of 1892. Having lost these I dropped the name, but in 1906 I found two or three well preserved specimens in the Naparima oceanic beds. Brady (Chal. Rep., page 702) says it is exclusively a Pacific species, and but for a few specimens found at about 8° N. it might be said to be peculiar to the South Pacific. Its bathymetrical range extends from 1,375 fathoms to 2,600 fathoms. The original description of the species was based on specimens from the chalk of New Britain (Geol. Mag., 1877, page 535).

Nodosaria abysorum. Though it is probable that there are not really more than about a dozen or so of true species of nodosaria, yet

the numberless varieties and gradations make it difficult to establish well defined species in that genus; and therefore when we come to questions of distribution we do not feel the same confidence in dealing with them as we do with better defined organisms. But *Nodosaria abysorum* has a character which, so far as I am aware, is not found in any other nodosaria. Many nodosarians have a spine or mucro at the apex or initial segment, and so indeed have some cristelarians and other related foraminifera, but none that I know of have more than one apical mucro except the one I have just named, and among the numerous nodosarias which appear in the Naparima oceanic beds of Trinidad this one is always distinguishable by the polymucronate apex. I have discussed the subject in the Geological Magazine, 1904, page 246, and need only refer to it here as supporting the theory of a connexion between the sea in which the oceanic beds of Trinidad were deposited and the Pacific Ocean. The only recent specimens of it were found at "Challenger" Station 296, south-west of Juan Fernandez, and it is not recorded from any other locality either as a living or fossil species, except the oceanic beds of Trinidad and the "Challenger" Station just named.

Further notes on tertiary fossils of the Caribean. The occurrence of *Ellipsoidina* in numerous individuals and varieties is another characteristic of the oceanic rocks of the Caribean region. The range of form of this foraminifer is from the original type of the genus *E. ellipsoides* Seguenza, in which all the chambers are embraced by the last, which alone is visible to the elongate and drawn-out forms exhibiting the whole series of chambers or segments, of which my *E. subnodosa* (figured in Proc. Zool. Soc., Lond., 1894) is an example. The genus seems to be abundant in the tertiaries of Italy and occurs also in Fiji and the Solomon Islands. *E. ellipsoides* and *E. exponens* have been found in the oceanic rocks of Barbados and Trinidad, and in the latter occur also *E. subnodosa* and a number of intermediate and allied forms. I now record *E. ellipsoides* and *E. subnodosa* from Jamaica.

The species of foraminifera I have just particularly dealt with are all remarkable and very distinct species and not mere varieties. They are such as could not have originated independently in different localities, and their occurrence in different regions can only be explained by migration. None of them are now living in the West Indies, but they occur in the Pacific, and *Ellipsoidina* is not known in the recent state. The conclusion seems irresistible that there was formerly a free communication between the Caribean region and the Pacific, and that the

elevation of the Isthmus of Panama or of the Andean region, or both cut off the Caribean area from the Pacific. The same explanation applies also to certain of the molluska, upon some of which I shall proceed to offer some remarks. I believe that crustacea and echinodermata will, when examined, furnish additional evidence in the same direction.

Arca patricia Sow. The likeness of this species to *A. grandis* of the Pacific was noticed by Carrick Moore and Sowerby in treating of the Haitian fossils. Sowerby described it as distinct under the name given above, but Gabb insisted upon its identity with the Pacific shell. In reporting on the Tobago fossils (Bull. Bot. Dep., Trinidad, 1903, page 541), I gave my reasons for keeping it under a separate name. This ark is highly characteristic of the Haitian miocene, and it occurs abundantly in the miocene beds of Trinidad and Tobago. It has no near relation in the existing fauna of the West Indies. No large ark now inhabits the Atlantic. It is remarkable, moreover, that this shell, together with *Purpura woodii*, *Rostelaria inornata* and a few others, have not been found in the miocene of Jamaica.

Chama antiquata Dall. I only mention the name of *Chama arcinela* here to observe that Dall has provided a new name for the miocene form and places the species in the section Echinochama Fischer. Thus in his list the West Indian miocene shell stands as *Echinochama antiquata* (Florida Fossils, Wagner Inst., Part VI, page 1404). Its Pacific analogue is *Chama californica* Dall. But the name Arcinela is sufficiently good as a sectional name, and thus for the present the name of the miocene form may stand as Chama (Arcinela) antiquata Dal.

Rostelaria inornata Gab. One of the most remarkable fossils of the Haitian miocene is that named by Gabb *Orthaulax inornatus*. It is, I believe, congeneric with *Strombus amplus* Brander of the European eocene, as noted in my paper on the Haitain fossils (Journ. Geol. Soc., Lond., 1876,page 520). Dall places it under the genus *Rostelaria* with two other miocene species of the validity of which I am doubtful, even though Dall has spent a good deal of labour in making out their characters (Florida Fossils, Wagner Inst., Part I, page 170). Dall is not inclined to entertain my suggestion that the shell may be referred to *Hipochrenes*, but that the differences are of doubtful importance can be seen by a comparison of Sowerby's figures in Min. Conch., Vol. V, Tab. CCXCVIII, CCXCIX, and CCC, Gabb's in Proc. Acad. N.S. Phil., 1872, Pl. IX; F. 3-4, and mine in Journ. Geol. Soc., Lond., 1876, Pl, XXVIII,

F.S., with that of the Egyptian shell given in Geol. Mag., 1898, Pl. XIX, F. 2. The name may stand in lists as *Rostelaria* (*Orthaulax* or *Hipochrenes*) *inornata* Gab. The form was probably an eocene and pre-eocene type, which migrated from Europe and Africa to the Caribean area, where it became extinct in miocene times.

Fusus henekenii Sow. This is one of the many species to which my remarks on the subject of nomenclature, &c., are applicable. The cabinet naturalist who maintains the identity of *Asaphis rugosa* and *A. deflorata*, and who would nevertheless regard *Sanguinolaria taheitensis* as a good species could never admit that *F. haitensis* was the same species as *F. henekeni*. Fortunately Gabb saw and admitted the identity, and thereby brought to light the fact that this is another of the species which having extinct representatives in the Caribean miocene has also living representatives in the Pacific (*F. dupetithouarsi*) and in the Caribean (*F. distans*). See Gabb, Costarican Fossils, Journ. Acad., N.S Phil., 1878, page 350. It may also be noted that many species of animals and plants have two forms, each of which is more different from the other than other distinct species are. *Fusus distans* and *F. henekeni* are examples of this fact.

Pyrula consors Sow. Gabb thought that this species found in the miocene, and recorded by him under the name of *P. melongena* (in this following C. Moore) was conspecific with the Pacific *P. pyrula* Brod. I left it in as *P. melongena*, though I had doubt on the subject. Dall decides that they are distinct, and in fact this species is in the same predicament as *Chama antiquata*, having a Pacific living representative (*P. patula*) and a living West Indian representative (*P. melongena*) besides fossil representatives in the miocene of Europe.

Purpura (*Cuma*) *woodii* Dall. This is the *Cuma tectum* of Gabb and myself. Dall's remarks on it seem to me very apposite and to be applicable more or less to other species found in the Caribean miocene, so that I quote them here. "The small distribution of *C. tectum* would harmonize with the hypothesis that the group had barely reached the Pacific from a miocene Antillean centre of development when the communication between the two seas was cut off, an event accompanied by geological changes in the Antilles which exterminated the parent stock." (Florida Fossils, Wagner Inst., Part I, page 155). Most of the species assigned to the section Cuma are merely varieties of *C. tectum*. The species is a purpura, and to make it into a genus would logically involve the making of a genus for nearly every species of Purpura.

There are several other species of Caribean miocene fossils upon which I should like to say a word or two, but I feel that I must bring my paper to an end. The proper place for further remarks would, no doubt, be a monographic review of the Caribean fossils. It is, however, unlikely that any such undertaking would ever fall to me.

It is, I think, pretty clearly made out that there was in tertiary times a land connexion between the Caribean and North Africa and a sea connexion between the Caribean Sea and the Pacific. The land connexion and the sea connexion probably existed in cretaceous times, and were in progress of slow alteration during later cretaceous time, and came to an end during the tertiary period, probably at the termination of the miocene, when the final remnant of the Atlantis disappeared and the Isthmus of Panama rose above the sea level, and the last gap in the Andes was closed.

A STORY OF A FRANKLIN SEARCH EXPEDITION.

By J. B. Tyrrell, M. A., F. G. S., &c.

(*Read 5th December, 1908*).

The Nineteenth Century has been characterized in many different ways, and many different titles have been suggested for it, mostly representing various phases of material progress and expansion. The titles so given undoubtedly designated some achievements that seemed to be of overmastering importance to us at the time, but in many cases these achievements will doubtless be overshadowed by greater accomplishments on the same lines, or in the same fields of work, in future. People are notoriously forgetful of the stages of material progress preceding their own, and there is a strong tendency among them to smile at the knowledge possessed by their ancestors when they think of the additions that have been made to that knowledge in their own times. Therefore while we who lived in it speak of the great material progress of the last century the coming generations are not unlikely to regard our titles and characterizations with smiles of easy tolerance rather than of approval.

If not material progress what then will stand out in history as the salient features of that century? In what field of endeavour did the curve of accomplishment reach its highest point? I venture to predict that nothing done during the past hundred years will overshadow the death-grip struggles and splendid achievements of the heroes of Arctic exploration, and that as year follows year into ages to come the heroic endeavours of these Arctic explorers will stand out more and more strongly in relief, and that the Nineteenth Century itself is not unlikely to be known as "The Century of Arctic Exploration."

During the first half of the century the energies of the explorers were chiefly devoted to the discovery of an ocean passage from the Atlantic to the Pacific north of the continent of America, which, ever since its discovery by Columbus had always been regarded by navigators as more or less of an obstruction or impediment in the course of trade with China and Eastern Asia.

The next quarter of a century or more was devoted to the search

for a definite knowledge of the fate of Sir John Franklin and his party, who perished in an attempt to discover the "North-West Passage."

Sir John Franklin had begun his naval career as a midshipman on the Polyphemus at the battle of Copenhagen, and later had made two arduous journeys by land across the continent of America to its northern coast for the purpose of surveying and exploring its then unknown shore. The two volumes now lying before me contain a well written and beautifully illustrated account of the hardships endured and the results accomplished on these journeys. Few more interesting accounts of travel and adventure have ever been written.

At a little later date other explorers almost completed the survey of the north west coast of America begun by Franklin.

Finally the British Government decided that the time had arrived to take advantage of the knowledge so obtained, and to despatch a marine expedition from England to the Pacific by this north coast, and so confident was it of success that letters for some of the officers were ordered to be addressed to the Sandwich Islands.

Accordingly two strong sailing ships, the *Erebus* and *Terror*, were fitted up and provided with auxiliary steam power, the first ships so provided for Arctic service, and were placed under the command of Sir John Franklin, who though now 59 years of age, was still very keen to undertake the enterprise. The crew all told consisted of 129 officers and men. On the 26th of May, 1845, with three years' provisions on board, the ships sailed from London for the Pacific Ocean, all hands being confident that at last the discovery of "the passage" was assured.

They sailed through Baffins Bay, up Lancaster Sound and Wellington Channel and then returned to Beechey Island, near the southwest angle of North Devon, where they spent the winter of 1845–6. What date they got out of their winter quarters at Beechey Island is not known, but during the following summer they sailed southwestward to Victoria Strait, off the northwest coast of King William Island, where, on the 11th of September, the two ships were beset in the Arctic ice pack. That winter was spent by the men in the ships surrounded by the Arctic ice, and probably their experiences were very similar to those of Nansen in the *Fram*, except that the men were much more closely huddled together, and that the ships were not so strongly built to resist the pressure of the ice.

On the 11th of June, 1847, Sir John Franklin died on board his

Map of the Arctic Coast of America, where Sir John Franklin and his Companions in the *Erebus* and *Terror* perished.

Scale 42 miles = 1 inch.

ship, the *Erebus*, but not before he had learned the glorious news that his work was accomplished and that he had discovered "the North-West Passage."

All that summer the ice remained firm around the ships, and the men's spirits must have sunk very low as they saw the prospects of reaching home and friends again disappearing into another Arctic winter. They knew too that even if all their provisions were good they would not last longer than the following summer, and there is a strong suspicion that much of the tinned meat with which they had been provided was bad.

That winter sickness and death took a heavy toll from the party and eight officers and twelve men died—a frightful mortality among the officers, showing that care, anxiety and idleness were telling heavily on them. But some hope doubtless came back to them with the return of the long days of spring, and it was determined to abandon the ships, and proceed up Great Fish River, and thence overland to Fort Resolution, the trading post of the Hudson's Bay Company on Great Slave Lake, dragging sleds with any supplies and provisions that they might have. A journey in boats up Great Fish River, or westward along the coast and then up the Mackenzie River might easily have been successfully undertaken during the preceding summer, before the provisions were exhausted, and probably it would have been undertaken at that time if Franklin had lived, but in his absence there was no one to efficiently direct travel except in the ships.

However on the 22nd of April, 1848, they abandoned the two ships and crossed the ice to Point Victory, the promontory nearest the ships on the west coast of King William Island. On the 26th they left Point Victory and started southward, dragging one or more heavy boats loaded on heavy sleds along with them. Before leaving they left a short memorandnm under a cairn of stones, and this, having been found by Sir Leopold McClintock some years later, is the only written record of the expedition that has ever reached the outer world.

A hundred and five men all told started south, and some reached as far as Starvation Cove, on the mainland just west of Point Richardson, where they died of starvation, while others returned to the ships, and all of these died either on the way back or at the ships.

The ultimate fate of the party was learned from accounts related by Eskimos living in the vicinity. These Eskimos also stated that one

of the ships had been crushed in the ice, while the other one drifted southward through Victoria Strait to a place called Oot-loo-lik, in the vicinity of Grant Point or O'Rielly Island, where it sank or was wrecked. The wreck was visited by these natives in the winter of 1857–8.

When Sir John Franklin and his companions did not return in 18.7 many searching parties were sent to look for them both by land and sea, but nothing could be learned of the course which they had followed or of their fate until, in 1854, Dr. John Rae, while exploring the isthmus of Boothia Felix, was informed by Eskimos that a great number of white men had perished of starvation on or near King William Island, off the north of the Great Fish River. Unfortunately he erroneously located the place where the last survivors were said to have reached as at Montreal Island, in the bay at the mouth of this river.

On the receipt of this information Sir George Simpson, the governor of the Hudson's Bay Company, instructed Messrs. James Anderson and J. G. Stewart, two officers of the Company, to start from Fort Resolution on Great Slave Lake with canoes, and proceed to the mouth of Great Fish River in order to determine certainly and finally the fate of their unfortunate countrymen.

This expedition was the first to visit the country where the white men had perished, and great results were expected of it. It fact, as will be seen later, it did reach to within a very few miles of Starvation Cove, where many, and perhaps the last, of Franklin's party died, and where the records of the voyage seem to have been left, and then, without accomplishing anything it turned homewards.

On the 22nd of June, 1855, Messrs. Anderson and Stewart, with three large birchbark canoes and a full complement of canoemen, started from Fort Resolution, but unfortunately without an Eskimo interpreter, or anyone who could understand the Eskimo language. Among the men who composed the party were "Thomas Mustagan" and "Paulet Papanakies," steersmen, and Henry Fidler, Edward Kipling and Joseph Boucher, midmen. On the 2nd of July the canoes left Great Slave Lake at the "Mountain" and by a series of portages leading to Aylmer Lake the divide at the head of Great Fish River was reached on July 11th, and Montreal Island at the mouth of that river on August 1st, forty days after leaving Fort Resolution. A number of

Eskimos were seen on the banks of the river, but in the absence of an interpreter no information of any importance could be obtained from them.

The following abstract of Mr. Anderson's journal will show how the few days at the mouth of Great Fish River were spent.

Thursday, Aug. 2. All hands but one were sent off to explore the (Montreal) Island. Messrs. Boucher and Reid returned and told us that they had found the place where a boat was broken or cut up, on a high ridge on the N. E. extremity of the island. Among the chips lying about was one with the name "*Erebus*" carved on it.

Friday, Aug. 3. Searched all day for graves but without success.

Saturday, Aug. 4. Time spent waiting for the ice to move to allow us to get across to the west shore.

Sunday, August 5. Crossed the channel to the western mainland, and divided into two parties, one going north and the other south.

Monday, Aug. 6. Explored along the shore, but the canoes are very much damaged and cannot be taken any further. Determine to proceed on foot with Halkett (collapsible) boat, and reach Point Pechell.

Tuesday, Aug. 7. After very early breakfast left to explore the coast to the north. At Point Ogle a piece of cod line and a strip of striped cotton were found. The party assembled late opposite Maconochie Island.

Wednesday, Aug. 8. Open water here enabled us to use the Halkett boat. Four of the best men were ferried across early in the morning to examine the island. If they discovered anything they were to signal, but nothing was found. The party returned from the island at 2 p.m., when they all started south and reached the canoes that night. (Starvation Cove is only a few miles west of Maconochie Island.)

Thursday, Aug. 9. Proceeded southward a short distance in the canoes.

Friday, Aug. 10. Continued southward, passed Montreal Island, and reached Point Blackburn at 11 p. m.

The Great Fish River was ascended with all possible speed, and its headwaters were reached on the 21st of August. On the 11th of

September Great Slave Lake was reached at old Fort Reliance, where Sir George Black spent the winters of 1833 and 1834, and from which in 1900 my brother, J. W. Tyrrell, started on his way to the Barren Lands to connect with the survey of the Dubawnt River which we had made together in 1893.

Messrs. Anderson and Stewart found no records or remains of any of the missing men of the Franklin expedition, and little or nothing was added by them to the knowledge that had previously been obtained by Dr. Rae.

Very little else was known of the history of this expedition, which is chiefly noted because it was the last party up to the present time to descend the Great Fish River to its mouth, until in the autumn of 1890 while travelling up the east shore of Lake Winnipeg, a little old French-Canadian named Boucher came to my camp. He said that he had been cook on the Anderson and Stewart expedition down the Great Fish River, and that he had an interesting story to tell if I would but listen to him.

He told of hardships and dangers that he and the other men encountered, or thought they did, but chiefly of the agony they suffered through fear that they would never again be brought back to their homes. However the most interesting part of his story was the statement that three men who were sent northward beyond Montreal Island (or Maconochie Island) to look for any signs of Sir John Franklin or his party saw one of the ships far out in the ice, but returned and reported that they had seen nothing, fearing that if they reported a ship in sight, their masters would take them to it, and they would not be able to get back to Fort Resolution that fall, and would all perish of starvation and exposure. This was doubtless the party sent on to Maconochie Island in the canvas boat on the 8th of August. The names of the three men given by him were Thomas Mustagan, Edward Kipling and Paulette Papanakies.

Thomas Mustagan was well known to me. He was the chief of the band of Ojibway Indians which had its headquarters at Norway House, near the north end of Lake Winnipeg, and though rather old at the time was a splendid type of physical manhood, besides having a good reputation as an honest, industrious man.

The others were not personally known to me, but after some enquiry Papanakies, who also was an Ojibway Indian, was found to be

living at Fisher River, while Kipling, a half-breed, was living at Keewatin.

Through the kindness of some friends the following statements were obtained from these three men.

Edward Kipling's Story.

Tom Mustagan, Paulet Papanakies, Henry Fidler and I were sent to the island.

In the morning we divided at an unknown island, Henry Fidler and I went to the west, and the other two to the east. We returned to the starting point in the evening and thence to the camp, where Paulet Papanakies told of having seen the ship far out in the sea. This information was not communicated to Messrs. Anderson and Stewart for the men were all tired of the expedition and were anxious to get home.

Next day we set out for Montreal Island, where Henry Fidler and I were sent on the west side. We saw the mark of the keel of a small boat that had been dragged across the island, and found the boat broken in small pieces on the eastern side. There were remains of Eskimo camps close to the broken boat. The Eskimo were supposed to be cannibals. (Note.—The story of the Eskimos being cannibals proved a very real difficulty in the way of obtaining canoemen for my journey through the Barren Lands in 1893. J.B.T.) We could find no other trace than the broken boat. We returned to camp that evening and next morning began the homeward journey. As the camps were broken up that evening preparatory to moving and we (Henry Fidler and I) were longer on the search than we had expected, nothing was reported about what we had seen on the east side of the island, namely the broken boat. When we returned to Fort Garry a portion of my wages was kept back until a settlement could be made. The balance has not been paid yet. We were told that medals had been sent us to York Factory, but we never received them.

(Sgd.) Edward Kipling.

Thomas Mustagan's Story, as reported by Mr. J. A. Campbell:

With regard to your inquiry I have interviewed old Tom Mustagan and others respecting "The Tale of a Ship," and have elicited the following information:— One of the Anderson and Stewart party,

Paulet Papanakies, on his return from the expedition repeatedly stated that he saw a ship far out in the ice at the mouth of the Great Fish River. Those whom I have spoken to say they have no reason to doubt the man's veracity. On some one suggesting that he might have been mistaken Paulet replied, "It was a very clear day, and I have seen the ship at York too often to be deceived."

Old Tom, who was on this expedition, gives the following account :— Paulet, Edward Kipling and I were sent off from the camp on the mainland in an inflated waterproof canoe to examine a chain of islands running far out to sea. There was open water between these islands and we proceeded from island to island, searching for remains as we went along. We found something on one of these islands, but I do not remember what it was. When we came to the last island but one, it was thought advisable that I, being the heaviest man in the party, should get out of the canoe, which was hardly up to our weight, and allow the other two to go on to the last island, which lay a long distance off. I was accordingly left behind. When my companions returned from this island, which was high and rocky, they reported that they had seen nothing. The expedition turned back shortly afterwards.

After we were disbanded Paulet told me and others at Norway House that he had seen a ship from the lofty island in question, and that he had begged Kipling to say nothing about it, because, if it were known that the ship was there, an attempt would be made to reach it, their frail craft would be crushed to pieces in the moving ice, and they would surely perish.

Tom goes on to say :—I believe Paulet saw the ship. Dr. Rae had previously been told that the ship was there, and had stated that he believed such to be the case. In fact it was on account of Dr. Rae's expressed belief in the Eskimo tale that the expedition under Messrs. Anderson and Stewart was organized.

PAULET PAPANAKIES' STORY, as reported by Mr. J. B. Johnston:

After saying the party left Norway House he thinks it was in the month of February, and other unimportant details, he goes on to say that a "Husky" who was fishing at the mouth of a river, the name of which he does not know, told him (Paulet) and Thomas Mustagan that a ship had been "ruined" and plenty people dead. They did not understand his language, but he made signs which they could readily follow,

and pointed to the place where the ship was all "broken." Paulet and Mustagan then proceeded to see if they could find anything, one going one way and one another, and it was Paulet only who from the summit of a rocky island saw quite distinctly what he still believes to be two masts of a ship. He says had there been more sticks standing around it would have been easy to have made a mistake, but there was nothing but rocks and ice as far as he could see. And in default of any kind of wood they were obliged to use the moss on the rocks to boil their kettle. Upon my enquiring why he did not tell the chief of the expedition what he had seen, he replied in the most simple manner possible, "Well, I was tired of the whole thing, and was thinking long to be home, and was afraid if I said anything about it, we should have to go back and see what it was, so I thought I would keep it to myself yet awhile anyhow." And it was some time after that he related to some of his comrades what he had seen. Pieces of iron and wood, portions of a boat, were found in the vicinity of where they were then camped.

This was told to me in a quiet deliberate manner, leaving no room whatever to doubt his veracity, or the sincerity of his belief. He is by no means an enthusiast. He views the whole thing as one of his many experiences. He is the remains of a strong man, of unimpaired faculties, and still after so many years wedded to the belief that he is not mistaken in what he saw. I must confess to being very much impressed by the man's statement, knowing as I do that where eyesight is concerned how very keen an Indian is, and how they will detect objects at a distance which you or I would overlook twenty times.

The statements of these men are given here for what they are worth. They were made in 1893, thirty-eight years after the events to which they refer. In the main points they agree with each other fairly well. That Paulet Papanakies believed that he saw a ship there can be little doubt, so that the tale cannot be set aside as simply unworthy of credence. Furthermore, it is difficult for a white man, unless he has lived a long time among natives, to appreciate the keenness of sight, and accuracy in observation common to Indians in the wilderness, and especially to such Indians as the Ojibways, who rank among the best hunters and woodsmen on this continent. Many travellers and others who know them best will bear me out in saying that inaccurate observations are almost unknown among them.

That these men were sent across to Maconochie Island is evident

from Mr. Anderson's journal, and from their own accounts it would appear that they left that island in the little portable boat, but what other island they reached is not known, and on account of our imperfect knowledge of the geography of the district it is impossible even to make a rational conjecture From the high point said to have been reached it is not impossible that Paulet may have seen the boat which had been taken to Starvation Cove, west of Point Richardson, where so many of the party died, or that the ship which finally sank at Oot-loo-lik first drifted into Simpson Strait to a point where it would be within range of vision, and then drifted back again westward to where it was unintentionally wrecked by the Eskimos.

In any event the story is interesting, not only as adding something to the knowledge of what became of Franklin's ships, but also as furnishing some slight insight into difficulties to be overcome by travellers who venture into remote parts of northern Canada.

THE DISTRIBUTION OF FAT, CHLORIDES, PHOSPHATES, POTASSIUM AND IRON IN STRIATED MUSCLE.

BY MAUD L. MENTEN, B.A., M.B.

(Read 30th January 1909.)

UNTIL comparatively recently definite knowledge concerning the distribution of inorganic and organic compounds in muscle fibre had been somewhat meagre. This is due, for the most part, to the fact that many of the microchemical methods have been only lately introduced into histological study; then, too, the small amounts in which these substances, and the mineral salts especially, occur, and the minute structure of striated muscle also render their demonstration difficult.

In the following pages are detailed a series of observations made during the last two years on the microchemistry of muscle fibre, chiefly of forms amongst the Insecta and Crustacea. These observations are, unfortunately, not at all as comprehensive as the author desired, but they may prove of service to other investigators and they are now, in consequence, put on record.

I—PREVIOUS OBSERVATIONS.

In 1899, Walbaum[1] studying the muscle of rachitic children for evidence of fatty degeneration, came to the conclusion that fat could occur in the muscle tissue independent of any pathological condition. In the latter part of his work not only did he find fat occurring in muscle which was apparently normal, but he was also able to demonstrate a more or less definite relation to the cross striation. This latter was especially evident in the eye muscles, in which the size of the fat droplet was proportional to the width of the striation. Using Sudan III and Hæmatoxylin staining Keinath[2] found large droplets of fat in proximity to the nuclei of the muscle, and fairly constantly grouped about either of their poles. In the striated muscle fibres of animals in almost every case fat arranged as droplets in longitudinal rows between the fibrils was distinctly discernible and in the muscles of the goat and dog the fibrils themselves contained fat in the form of very fine granules but in varying numbers and sizes and with no definite arrangement that could be recognized. In human muscle which was normal, and in the pathological where the structure of the

fibril was not destroyed, he obtained similar results, but in no case was he able to discover that the fat bore any relation whatever to the cross striation.

Of the mineral constituents of the muscle, the only element whose distribution has been studied microchemically is potassium. Macallum[3] has shewn that the salts of this metal possess a definite arrangement in the fibrils of uncontracted striated muscle, being limited to the dim band in the wing muscles of insects and the claw muscles of the crayfish but the potassium reaction was most marked in those zones of the dim band which are adjacent to the light bands. In the contracted fibril on the other hand he found that the most marked reaction for potassium was given by the central zone of the dim band. When, however, the penetration of the reagent (the hexa-nitrite of cobalt and sodium) is tardy there occurs a redistribution of the potassium salts in the fibres and in consequence the potassium demonstrated was sometimes in the light bands alone and sometimes along the line of separation between two adjacent light and dim bands.

II—THE LOCALIZATION OF THE FAT.

To show the microchemical distribution of fat the reagent used was Scarlet Red, a stain belonging to the Tetrazo Compounds. This substance was introduced into microchemistry by Michaelis who studied its composition and properties, and by whom it was classed in the group of indifferent staining materials, which also includes Sudan III. It is insoluble in water, alkalies and acids, with the exception of concentrated sulphuric acid with which it gives a blue colour, soluble in alcohol and is readily dissolved in the fats. Its action is very much more extensive than osmic acid, which reacts only with unsaturated fatty compounds, such as oleic acid and olein, yet it stains nothing but the fats, whereas the osmic acid may be secondarily reduced by substances other than the oleic compounds, and the resulting black precipitate may represent more than the distribution of the fat.[5] Michaelis explains its action by the fact that it belongs to the indifferent substances, i.e, those possessing no salt-forming group and whose acid or basic properties are so weak as to be practically negligible and, therefore, the staining process is a physical rather than a chemical one, but that in order to be soluble in the fat the molecule of the staining compound must have a characteristic chemical composition. This latter statement seems to be borne out by the observation that palmitic and stearic acid crystals stain with some difficulty by Scarlet Red and

Sudan III at ordinary temperatures, but when either of these fats is heated to the melting point in contact with the fat stain the whole becomes a deep red. However on recrystallization on cooling the majority of the crystals fail to retain their coloration. Mann[6] does not accept the physical explanation for the staining of the fatty materials, and suggests that the process is rather one of oxidation.

The solution used was one prepared by dissolving the Scarlet Red powder in 70 per cent. alcohol and allowing it to stand several days. Fischer[7] claims that a solution made with 70 per cent. alcohol at the boiling point or leaving the solution in a parrafin oven for 24 hours, produced better results in a much shorter period of time. However, in my experiments the additional heating apparently had little effect in accelerating the staining and both solutions required, comparatively speaking, the same time to give like results.

Before using the solution all sediment should be removed by filtration. Any excess of the stain may be washed off with distilled water, as washing in alcohol, even if of a weak dilution, dissolves out more or less of the fat, and it is, therefore, not to be recommended. The muscle tissue which was found most advantageous for these microchemical investigations was that of insects, owing to the size of the fibrils and their greater development. In many cases fresh tissue was used while in other experiments the muscle was previously fixed in 4 per cent. formaline or a 5 per cent. solution of chloral hydrate. Previously to being placed in the Scarlet Red, the fibres must be thoroughly separated so as to facilitate the penetration of the reagent to every part. While a reaction obtains in ten to fifteen minutes it appears only in the larger fat droplets or those most readily accessible to the staining fluid and the best results, both in detail and distinctness, were obtained by leaving the tissue in the solution for five days. When allowed to remain longer than this in the staining fluid no further trace of fat was revealed, and apparently the reaction was not in any way increased.

When muscle fibres treated according to the methods outlined above are examined microscopically the fibrils are seen to be transversely marked by bright red bands, occurring at regular intervals throughout the entire length of the fibre, and under a high magnification these striations are found to be beaded or made up of fine granules, which here and there have coalesced to form small globules. These striæ lie in the dim band, one being along Hensen's line, across

the centre of the dim band and another on either side of this at its upper and lower borders. In some case Hensen's line appears as an exceedingly fine faintly colored thread (Fig. 3) and as the particles which compose it are often so fine as to be only discernible in the ultramicroscope, some conception may be had of their minute size. In many cases, however, the line appears equal in width to those on either side of it (Figs. 4 and 5).

That this substance is undoubtedly fat is shewn by the fact that the fat solvents readily remove it from the fibres and if these are employed previously to the staining of the tissue with the Scarlet Red either no indication of the reaction appears, or one of very much lessened intensity depending on the time the solvent has been in contact with, and how readily it has penetrated the muscle fibres. For the purpose of demonstrating this, muscle previously fixed in formol was treated first with 70 per cent. alcohol for four hours then with absolute alcohol for twelve to twenty-four hours and finally with ether for from twenty-four hours to one week. The preparations were afterwards repeatedly washed with alcohol until every trace of ether was removed from them. Subsequent treatment with Scarlet Red fails to reveal any trace of a colored striation if the tissue has been sufficiently teased to allow a complete penetration of the ether.

Where the tissue has not been thoroughly separated, although the muscle has remained in the ether for several days, the fat is not completely dissolved out and the fibrils give on treatment with Scarlet Red a reaction characteristic in its distribution but of a much fainter colour. The final extraction of the fat occurring normally in the muscular tissue, is as Bogdanow[8] has shewn very difficult to obtain. He found that even after repeated extractions in a Sohxlet apparatus with ether he could obtain a reaction with osmic acid in the muscle fibre.

When the myoplasm surrounding the fibril has not been removed by the teasing, it stains a deep homogeneous reddish orange (Fig. 2) which apparently indicates a diffuse distribution of the fat in that structure.

The distribution of the fat is not constant in any one part of the fibre alone. Most frequently it appears in the dim band, but it may occur only in the light band, and, occasionally, simultaneously in both. This variation seems to be intimately connected with the activity of the muscle, i.e., whether the muscle is in the resting or contracting stage.

In the majority of the preparations studied the reaction is confined to the dim band, which is marked by regularly occurring longitudinal lines of a beaded character (Figs. 7 and 8). The droplets are usually of uniform size and depth of colour, and in some instances they form a continuous and unbroken line throughout the length of the dim band (Fig. 8) while in others there is a tendency for the fat to be aggregated in the outer zones of the dim band, leaving a narrow space immediately in the centre of the band, which is absolutely free from any trace of the scarlet stain (Fig. 7). This massing of the fat towards the poles of the dim band may advance yet farther until the fat appears at the extreme edges of the dim band with occasional faintly colored droplets in the central part (Fig. 8).

Frequently, however, the fat is wholly limited to the light band (Fig. 10). An approximation to this condition is shewn in Fig. 9, where the greater part of the fatty material lies in the outer thirds of the light band, but an occasional trace is also visible in the dim band. The striated character of the reaction is to be observed in the fat occurring in the light as well as in the dim band. The granules are visible in both cases and they always occur in longitudinal lines. Among those fibrils which had been subjected to treatment with Scarlet Red for five or more days occasionally was to be seen a result as represented in Fig. 11, where a granular longitudinal striation appeared in the light band, and an additional thin line of fainter colour, occurred in the dim band marking the position of Hensen's line. The longitudinal granular character which is so distinctly marked in the dim band is maintained in the reaction along Hensen's line. In the centre of the light band, extending horizontally across it, along Dobie's line, is a narrow space devoid of any coloration.

A clue to the explanation of these diverse pictures of the distribution of the fat is obtained from those fibres which have been fixed while a wave of contraction was passing over them (Fig. 12). In the lower contracted part of the fibril the fat lies wholly in the dim band, the centre of which is devoid of any reaction in contrast with the deeply stained red granules, regularly arranged in longitudinal lines in the zone on either side of this. In the upper part, where the fibre is uncontracted the dim bands shew only a diffuse reaction pale in colour with the fat in granules arranged along the borders adjacent to the light bands. The assumption, therefore, is that Fig. 7 represents the distribution of the fats in complete relaxation and Fig. 11 that of complete contraction, and the various intermediate stages are indicated in Figs. 8, 9, and 10.

Results quite similar to those obtained with Scarlet Red were obtained also with another fat staining reagent. J. Lorrain Smith[9] after a somewhat extensive study of the action of the different basic dyes, including Methyl Violet, on fatty acids and numerous fatty compounds, concluded that the reaction between the fat and the dye which he obtained was due to the formation of a colored soap. In that case Methyl Violet should demonstrate in muscle tissue the same distributiou of fat as was observed when Scarlet Red was used and to test this a number of experimental observations were made. Part of the muscle tissue, which had been previously fixed in 4 per cent. formalin or 5 per cent. chloral hydrate solution, and from which fibres treated with Scarlet Red gave characteristic results as described in the foregoing pages, was stained in Methyl Violet. The result was in every way comparable to that obtained with the Scarlet Red except that in these latter experiments the fats were colored violet instead of red. When tissue fixed in absolute alcohol was used, if the fibres were thoroughly separated a very faintly colored reaction resulted.

It was further, found that if the fibres were left in ether for several days, (using a technique in every way similar to that already mentioned in the Scarlet Red experiments with ether extraction) and then stained with the Methyl Violet, the fibrils where they had been sufficiently separated by teasing, shewed a pale mauve colour, barely perceptible in the striations. The Methyl Violet undoubtedly stained a substance with a distribution analogous to that which gave a reaction with the Scarlet Red and which further was soluble both in alcohol and ether.

Whether other constituents of the muscle fibre which are soluble in ether stain with Methyl Violet cannot at present be determined. One compound, creatin, present in the dim bands is soluble in water and alcohol but is not soluble in ether and therefore it does not play a part in the fixation of the dye.[10]

That Methyl Violet does stain fats very deeply was shown in the case of lecithin. When glass slides were smeared with a thin film of this fat, treatment for a few minutes with a solution of the dye gave an intensely deep violet coloration. When similar films were treated with solutions of Scarlet Red the resulting red stain was equally intense. With other fats, e.g., olive oil, the reactions were similar and as pronounced.

III—THE LOCALIZATION AND THE DISTRIBUTION OF THE CHLORIDES.

In the various analyses of the inorganic constituents of muscle from different animals there is shewn a marked variability in the amount of the chlorides. This chloride content is especially high in the invertebrates and Henke[11] found on estimation of that mineral in Octopus as much as 2.7977 grams in 100 parts of the dried muscle. It is remarkable, too, that in the table of percentages, which Katz[12] gives as the result of his analyses of various muscle tissues, the quantitative amount of chlorides in invertebrate muscle is so much greater than that in the muscle of the vertebrates.

The salt water shell-fish examined by him gave 1.2477 per cent. of chlorine (dried muscle) in comparison with 0.0935 per cent. and 0.3415 per cent. which represent respectively the minimal and maximal amounts obtained from the vertebrate muscle. This excess cannot be explained wholly by the fact that chlorine forms one of the preponderating elements in the medium in which they live, for if so, a similarly high percentage would be found but was not observed in the muscle of the marine fishes, which he analyzed.

In all estimations of the chlorine content of muscle it is a question whether any or all of the chlorine found is localized in the fibre, that is, within its sarcolemma and if within the fibre in what portions of each fibril. The observations now detailed bear on the latter part of this problem.

The method of studying the distribution of the chlorine of chlorides was the same as that already used by Macallum and Menten,[13] to shew the distribution of the chlorides in the nerve fibre, and a detailed description of the method appeared in the account of that work. The reagent used was a decinormal solution of silver nitrate, to which was added enough of nitric acid to give the reagent 1.5 per cent. of the acid. The reagent must be prepared with water free from any trace of chlorides, and the tissue should be teased with glass or quill points to preclude the possibility of any contamination with the same impurity.

To obtain good results the fibrils must be completely separated as the reagent penetrates the tissue comparatively slowly when in a mass. The best preparations were obtained after an immersion in the nitrate

solution for three days, but usually a few hours sufficed to give forms showing typical distributions.

When sufficiently acted upon by the reagent the muscle fibres were mounted directly on a slide in 50 per cent. glycerine, and placed in direct sunlight for several hours. Teased out thorax muscle fibre of insects which has been for four or five days in contact with a solution of the silver nitrate containing nitric acid, and then exposed to the sunlight, shews the fibrils marked by a transverse striation, similar to that obtained in the preparations demonstrating the distribution of the fat. The striae are granular, of a deep brown colour and they occur at regular intervals throughout the entire length of the fibre (Fig. 16). In addition to the deeply colored brown precipitate a diffuse reaction is frequently noticed in the light bands, perhaps in part due to a more rapid penetration of the nitric acid, and a consequent slight redistribution of the chlorides.

That the chlorides are not limited to the peripheral layers of the fibre, but extend in horizontal planes across it, may occasionally be observed in favourable preparations (Fig. 18). The granular character of the precipitate is distinctly recognizable, individual granules being readily discernible. On careful examination the division into dim and light bands is easily distinguished, and the chlorides are seen to be localized in the dim bands. At its upper and lower edges near the junction with the light bands. The reaction in this part of the fibril is very intense, and on prolonged treatment with silver nitrate a third striation frequently appears also in the dim band, but this is of a much fainter colour. This additional striation lies exactly in the centre of the band, marking the position of Hensen's line (Fig. 17).

Although the muscle tissue, unless in a finely divided condition, is very slowly penetrated by the reagent the reaction may occasionally be observed in a considerable number of contiguous fibres, which have not been separated and in these cases the striæ appear as discs extending horizontally across several fibres (Fig. 19).

The distribution of the chlorides in the dim band, however, is more readily demonstrated in the wing muscles. The whole fibre is marked by many longitudinal striae (Fig. 20) lying along definite straight lines and parallel to one another. At the first glance, it appears as if these regularly distributed, deep brown lines were continuous throughout the entire length of the fibre, but a careful examination reveals the fact

that there is an interruption in the light band which rarely contains any of the darkened sub-chloride of silver. Each stria is composed of fine granules, which are the colored particles.

The chlorides, however, are not always confined to the dim band, and although amongst the preparations studied, this seemed to be the distribution, which most frequently obtained, the reverse picture is often met with, the chlorides being aggregated at the junction of the light and dim bands, while the dim band itself appears comparatively free from any reaction. In Fig. 22, for example, the silver salts are shown massed along the upper and lower border lines of the light band, and only a few scattered granules of a faint colour appear to lie in the dim band. Fig. 21 represents the chlorides occurring simultaneously in both the light and dim elements of the muscle fibre, and while the greater part of this inorganic material appears in regularly distributed vertical lines in the dim band, frequently these lines are continued into the light band.

Since the reaction may be well marked on the borders of the light band and the dim band be devoid of any coloration, and vice versa, the result can hardly be due to a redistribution caused by the advance of the penetrant acid being more rapid than that of the silver nitrate for in these cases a diffuse reaction also occurs. Hence it is inferred that there is an alteration or rearrangement in the disposition of these salts, which has some definite relation to the activity of the muscle.

It can scarcely be doubted but that these various striations represent the arrangement of the chlorides as they obtain in the living muscle. It is true that striæ may result (as in the Boehm-Liesegang phenomena) from a uniform distribution of inorganic salts in solutions of definite consistency as has been experimentally shewn by treating mixtures of albumen and of gelatine in glass tubes or plates with certain silver salts and then exposing the preparations to the sunlight. In these cases, however, the striæ and the interstriate zones are of varying widths, being wider and less sharply defined as the reaction progresses in the direction of the line of diffusion; also the depth of the reaction in each gradually decreases from the central point peripherally. In the muscle, on the other hand, the tone of reaction throughout the individual fibres is constant and the striations are sharply defined. When variations in the width of the striæ do occur they may be explained as due to the differences in the width of the dim bands.

The distribution of the chlorides in striated muscle, therefore, as evidenced in the preparations obtained may occur either in the dim band chiefly, or alone, or in the light and dim band, the distribution depending, apparently, upon the phase of activity existing in the fibril at the moment of fixation.

IV—THE LOCALIZATION AND THE DISTRIBUTION OF THE POTASSIUM

An exceedingly sensitive reagent to shew minute traces of potassium was introduced into microchemistry by Macallum [14] in his work on the distribution of that element in plant and animal tissue. This compound, the hexanitrite of cobalt and sodium, $Co\ Na_3\ (No_2)_6$, with even a minute quantity of potassium either free or in combination gives an orange-yellow precipitate, which is rendered more evident by adding ammonium sulphide, after the tissue has been washed from every trace of the uncombined cobalt salt. The resulting black sulphide indicates the distribution of the potassium. The method of preparing the reagent employed was the same as that used by the above mentioned author, and full details are given in the account of his work. It is prepared by dissolving twenty grammes of cobalt nitrite and thirty-five grammes of sodium nitrite in seventy-five c.c. of water containing ten c.c. of glaciol acetic acid. The solution was then diluted to 100 c.c. In the early part of the work the reagent used was of this composition, but owing to its somewhat slow penetrability into the muscle fibrils, better results were subsequently obtained with a solution diluted with a third or one-half of a fifty per cent. solution of sodium nitrite. Care was taken that every trace of the uncombined cobalt reagent was removed from the tissue before it was treated with the ammonium sulphide, as otherwise a reaction would take place between the uncombined cobalt salt and the sulphide, thus giving a black precipitate. The preparations were mounted in fifty per cent. glycerine.

From the various analyses of striated muscle, potassium forms one of the predominating elements amongst the inorganic constituents and because of this preponderance the tissue readily lends itself to microchemical investigation of this metal, which gives most distinct and characteristic results. Macallum has already shewn that these salts are definitely distributed in muscle. The same author has also pointed out that the cobalt reagent gives with creatin a constituent of vertebrate muscle, a precipitate similar to that obtained with the potassium salts.

To obviate the difficulty arising from this fact all the experiments here detailed were carried out upon insect muscle, which is free from that compound or possesses it only in infinitesimal quantities. The reaction in the tissue is in all cases immediate, the maximum result being obtained in 3 to 5 minutes. Leaving the muscle fibres in contact with the reagent for a longer period of time in no case intensified or enhanced the results.

The tissue must be fresh and thoroughly teased-out, and for this purpose glass points or quills were used. The teased-out material, without further treatment, was then placed in the cobalt solution for five to fifteen minutes, washed thoroughly in ice-cold water, and mounted on a slide in equal parts of glycerine and concentrated ammonium sulphide. The wing muscles of insects shew the distribution of this salt in a remarkable manner and throughout a marked resemblance is observed to the results obtained with the reagents for the chlorides and fats. The potassium as in the case of the two above mentioned muscle constituents may be restricted to either the dim or to the light band, or it may occur simultaneously in both. When the dim band alone is affected a longitudinal striation is more or less clearly marked (Figs. 24-25) and this may possess a granular appearance extending continuously through the dim band (Fig. 25) or it may be limited to the two zones forming the upper and lower third of this band while the central third is comparatively free (Fig. 26). The striations when restricted to these latter situations, i.e., the upper and lower thirds of the dim band, do not possess a granular character, or if so, it is difficult to distinguish.

In Fig. 24 a marked condensation of the potassium is evidenced along the extreme border line of the dim band, and also midway between these, along Hensen's line.

When the potassium is localized in the light band apparently, it may occur in the longitudinal striation, an example of which is represented in Fig. 28, or it may be irregularly disposed (Fig. 30) without any trace of striation. An approximation to the restriction of this inorganic material to the border of the light band is occasionally met with (Fig. 27) where, many of the striations are confined entirely to this part of the fibre. Such preparations afford conclusive evidence of the change in position of the inorganic constituents. That this redistribution is intimately connected with the activity of the muscle seems apparent from such fibres, as those represented in Fig. 31, where a wave of contraction is advancing upward over the muscle. In the lower part

of the figure the potassium is isolated in the dim band, in the upper contracted part it occurs in the vicinity of the light band and between the two extremes the intermediate grades are obtained.

As already mentioned a comparison of the distribution of the chlorine of chlorides with that of potassium in muscle reveals a remarkable similarity in the disposition of the two, hence the inference that in striated muscle they possess an analogous distribution.

Also to be noted is the ease with which the fibril may be broken across at the light band, when it is free from any reaction. This structure may become so reduced in size as to be scarcely discernible except where the fibrils have become divided transversely (Fig. 25) through pressure on the cover glass.

V—THE DISTRIBUTION OF THE PHOSPHATES.

If fresh tissue, after having been thoroughly teased, be left in a decinormal solution of silver nitrate, the phosphates, chlorides and some other constituents of muscle which unite to form insoluble compounds with silver are precipitated, and in the sunlight these compounds are reduced, and assume a deep brown colour. The reagent should be prepared from distilled water free from any chemical impurity and every precaution should be observed to prevent the tissue becoming chemically contaminated. In these experiments as in those demonstrating the chlorides and potassium only glass or quill points should be used for teasing purposes. A characteristic reaction is obtained when the fibres have been in the reagent about three days, after which the tissue is then mounted in 50 per cent. glycerine and exposed to the action of direct sunlight.

The compounds in muscle fibre other than the chlorides and phosphates which unite with silver to give "reduced" silver products in sunlight, are probably present only in infinitesimal quantities and thus when the reagent is allowed to act on muscle fibre in the manner described the result is due to "reduced" silver phosphate and chloride. If the preparations before exposure to sunlight are treated with dilute nitric acid the "reduced" phosphate does not appear subsequently. Consequently, by comparing preparations made to show the chlorides alone with those treated with nitrate of silver but not with dilute nitric acid, one is enabled to determine, not strictly and definitely, but on the whole approximately, the distribution of the phosphates. By compar-

ing Figs. 32-38, which illustrate the phosphate reaction, with Figs. 16-22 which represent the distribution of the chlorides, one may determine what the localization of the phosphates is.

Next to potassium the phosphates are the most abundant inorganic constituents of striated muscle. Consequently the microchemical determination of their distribution is important. Invariably results analogous to those obtained in the chloride and potassium investigations, show the distribution of the phosphates to be the same as in the case of the chlorides and potassium salts. A most clearly marked precipitate possessing a granular character occurs along the edges of the dim bands, and a more faintly colored reaction at the central part indicates Hensen's line (Fig. 34). This represents a typical distribution and when, as in Fig. 33, the phosphates seem to occupy the whole light band, it is to be explained by the fact that this structure has become so narrowed that its appearance is obliterated by the juxtaposition of the lines of the precipitate which really occur in the edges of the dim band. The disposition of the phosphates in the wing muscle, too, bears a striking resemblance to that already demonstrated in the case of the chlorides and the potassium. Comparing Fig. 28 with Fig. 37, which respectively represent the distribution of the potassium and the phosphates on the borders of the light band, one sees the same localization obtaining in both, and further in Fig. 22, which represents the distribution of the chlorides there is an approximation to the same condition.

A comparison of Figs. 21 and 35 likewise reveals an analogous disposition of the chlorides and phosphates in the dim band, and the potassium shews a strikingly similar arrangement in Fig. 25.

Occasionally in the wing muscle fibres there is a tendency which is also met with in the potassium preparations, towards an irregular distribution of these salts in the light band. This departure from a regular arrangement of these inorganic constituents has been observed only in this part of the fibril, never in the dim band where the precipitate always possesses a distinctly longitudinal striation, and usually a definite granular character.

From the foregoing observations it is apparent that the chlorides, the phosphates and the potassium have an analogous distribution and it is justifiable, therefore, to conclude that the definitely localized arrangement displayed by all of them is associated in some way with activity of the muscle.

VI—THE IRON IN MUSCLE FIBRE.

For the demonstration of iron in the muscle fibres the reagent employed was hæmatoxylin, which has been shewn by Macallum to be a very sensitive one to determine the presence of iron in an inorganic combination. When inorganic compounds are treated with a 0.5 per cent. aqueous solution of hæmatoxylin the iron is represented by a blue-black reaction, but if the iron is present in the organic form no change in colour occurs. This latter may be converted into the inorganic form by the action of acid alcohol and when this is treated with the hæmatoxylin it gives the blue-black reaction above referred to. The acid alcohol used for this purpose was one containing four volumes of concentrated sulphuric acid in 100 parts of absolute alcohol in which the tissue was left for at least fifteeen hours at a temperature of 35° C. This tissue was previously fixed in a four per cent. solution of formaline and, after all the formaline was removed by washing thoroughly in alcohol, was transferred to the sulphuric acid alcohol in which the preparation remained for fifteen to twenty-four hours at 35° C. All traces of the acid were then removed by washing with absolute alcohol and the fibrils finally stained in the hæmatoxylin solution for thirty minutes. They were then mounted in 50 per cent. glycerine.

Using the aqueous hæmatoxylin alone on the fresh muscle tissue or on that previously fixed in alcohol or formaline there appeared in the fibrils only a slight yellowish brown coloration with a somewhat deeper colour in the narrow light band. The nuclei were stained a like diffuse yellow colour but with extremely fine darker granules scattered throughout (Fig. 13).

Apparently the muscle fibril and the nucleus contain, if any, only an infinitesimal amount of inorganic iron. When the muscle has been treated with the acid alcohol and then subjected to staining with aqueous hæmatoxylin solution a general, diffuse, faint purplish tone obtains in the dim bands, with more deeply stained, extremely fine granules irregularly distributed through them and what occupies the position of the narrow light band presents a very deep purplish colour (Fig. 14). In the nuclei the reaction is most intense especially along the chromatin threads (Fig. 15). When the myoplasm in which the fibril is embedded is not removed by the teasing, it takes a deep purple colour, equal in intensity to that obtaining in the light band, and the

reaction manifested in the latter indicates a diffuse distribution of the organic compounds of iron in that structure.

Since the depth of colour in vicinity of the light band approaches in intensity that in the chromatin threads, it is inferred that the amount of organic iron in this locality is a little less than in the chromatin. Since, however, the material used for this purpose was rather limited in quantity it is perhaps best not to insist too much on an interpretation of the phenomena observed.

In conclusion I wish to express my sincere thanks to Professor A. B. Macallum, for suggesting the subject of this research, and for his supervision throughout the course of the investigations.

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EXPLANATION OF FIGURES ILLUSTRATING THE MICROCHEMISTRY OF STRIATED MUSCLE.

Fig. 1.—Thorax muscle,—Bee, fixed in 4 per cent. formalin and stained in hæmatoxylin and eoxin. The more deeply stained sheaths enclosing portions of the fibrils and fragments of the adherent myoplasm × 1000.

Figs. 2—6.—Thorax muscle,—Bee fixed in 4 per cent. formalin and stained in Scarlet Red, 10 to 15 minutes. In Fig. 2, the part of the fibre stained orange represents the myoplasm × 1000.

Fig. 7.—Wing muscle, *Tenebrio obscurus*. Fixed in 2 per cent. formalin stained with Scarlet Red, 10 minutes × 1000.

Fig. 8.—Wing muscle, *Tenebrio obscurus*. Fixed in 2 per cent. formalin and treated with Scarlet Red, 75 hours, shewing the fat confined to the dim band × 1000.

Fig. 9—10—Wing muscle, *Tenebrio molitor*. Fixed in 2 per cent. formalin and stained with Scarlet Red, 75 hours. In both the fat occurs chiefly in the light bands × 1000.

Fig. 11.—Wing muscle, *Tenebrio molitor*. Fixed in 2 per cent. formalin, stained with Scarlet Red, 125 hours. A deep reaction obtains in the light band, but the central zone, which marks the position of Dobie's Line is free from fat. In the dim band a faint reaction occurs along Hensen's Line × 1000.

Fig. 12.—Wing muscle, *Tenebrio obscurus*. Fixed in 2 per cent. formalin and stained in Scarlet Red, 125 hours, shewing a fibre partly relaxed and partly contracted × 1000.

Fig. 13.—Thorax muscle, Bee. Fixed in 4 per cent. formalin, stained with 2 per cent. aqueous hæmatoxylin, 36 hours. × 1000.

Fig. 14.—Thorax muscle, Bee. Fixed in 4 per cent. formalin and treated with absolute alcohol, and then sulphuric acid alcohol, 24 hours, stained with 2 per cent. aqueous hæmatoxylin × 1000.

Fig. 15.—Preparations of same shewing the reaction for organic iron which obtains in the nuclei × 1000.

Fig. 16.—Muscle, *Lachnosterna fusca*. $\frac{N}{10}$ $AgNO_3$ + 1.5 per cent. HNO_3, 48 hours, × 1000.

Fig. 17.—Muscle, Wasp. $\frac{N}{10}$ $AgNO_3$ + 1.5 per cent. HNO_3, 5 days. The faintly marked reaction represents Hensen's Line × 1335.

Fig. 18.—Muscle, *Lachnosterna fusca*. $\frac{N}{10}$ $AgNO_3$ + 1.5 per cent. HNO_3, 48 hours, showing the distribution of the chlorides extending in horizontal plane across the fibre × 1000.

Fig. 19.—Muscle, *Lachnosterna fusca*. $\frac{N}{10}$ $AgNO_3$ + 1.5 per cent. HNO_3, 48 hours × 1000.

Fig. 20.—Wing Muscle of *Calosoma Scrutator*. $\frac{N}{10}$ $AgNO_3$ + 1.5 per cent. HNO_3, 5 days × 1000.

Fig. 21.—Wing Muscle, Wasp. $\frac{N}{10}$ $AgNO_3$ + 1.5 per cent. HNO_3, 5 days × 1000.

Fig. 22.—Wing Muscle, Wasp. $\frac{N}{10}$ $AgNO_3$ + 1.5 per cent. HNO_3, 18 hours, shewing the distribution of the chlorides at the extreme edge of the dim band, and at the border of the light band × 1000.

Figs. 23-31.—Preparations treated with cobalt solution, $Co\,Na_3\,(NO_2)_6$, and ammonium sulphide.

Fig. 23.—Wing Muscle, *Tenebrio molitor*. Cobalt solution 67 parts + 50 per cent. sodium nitrate solution, 33 parts, 5 minutes × 1000.

Fig. 24.—Wing Muscle, *Calosoma Scrutator*. Cobalt solution 50 parts + 50 per cent. sodium nitrite solution 50 parts, 2 hours, shewing an aggregation of potassium at the border of the dim band, and along Hensen's line × 1000.

Fig. 25.—Wing Muscle, *Tenebrio Obscurus*. Cobalt solution 67 parts + 50 per cent. solution of sodium nitrite, 33 parts, 5 minutes. The light band in this preparation is so narrowed as to be practically indistinguishable except when the fibres break at this point × 1000.

Fig. 26.—Wing Muscle, *Aeschna*. Cobalt solution 50 parts + 50 per cent. sodium nitrite, 50 parts, 2 hours. Central zone of the dim band free from potassium holding material. Light band also shews no reaction × 1000.

Fig. 27.—Muscle Fibre, *Calosoma Scrutator*. Cobalt solution 50 parts + 50 per cent. sodium nitrite, 50 parts, 2 hours × 1000. Central third of dim band free from potassium.

Fig 28.—Wing Muscle, *Tenebrio molitor*. Cobalt solution, 50 parts + 50 per cent. sodium nitrite, 50 parts, 5 minutes. Shewing the localization of potassium at the junctions of the light and dim bands × 1000.

Fig. 29.—Wing Muscle, *Tenebrio molitor*. Cobalt solution, 15 hours. Reaction obtaining only on the borders of the light band × 1000.

Fig. 30.—Wing Muscle, *Tenebrio*. Cobalt solution, 15 hours. The distribution of the potassium wholly in the light band × 1000.

Fig. 31.—Wing Muscle, *Tenebrio*. Cobalt solution 50 parts + 50 per cent. solution of sodium nitrite, 50 parts, 5 minutes. Shewing a fibre as a wave of contraction is passing over it × 400.

Figs. 32-38.—Preparations treated with $\frac{N}{10}$ $AgNO_3$.

Fig. 32.—Muscle, *Lachnosterna fusca*. $\frac{N}{10}$ $AgNO_3$, 40 hours × 1000.

Fig. 33.—Thorax Muscle, Bee. $\frac{N}{10}$ $AgNO_3$, 5 days × 1000.

Fig. 34.—Thorax Muscle, Bee. $\frac{N}{10}$ $AgNO_3$, 5 days × 1000.

Fig. 35.—Wing Muscle, Wasp. $\frac{N}{10}$ $AgNO_3$, 18 hours × 1000.

Fig. 36.—Wing Muscle, *Calosoma*. $\frac{N}{10}$ $AgNO_3$, 60 hours × 1000. Phosphates, distributed in the borders of the dim band adjacent to the light bands × 1000.

Fig. 37.—Wing Muscle, *Desmoceros palliatus*. $\frac{N}{10}$ $AgNO_3$, 4 months × 1000.

Fig. 38.—Wing Muscle, *Benacus grisea*. $\frac{N}{10}$ $AgNO_3$, 10 days × 1000.

ON THE ORIGIN OF LIFE ON THE GLOBE.

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There are some subjects upon which the highest intellectual interest of mankind will always be directed. Amongst these are the nature and origin of matter, the illimitable extent of the universe, the nature of the processes underlying thought, the origin and development of man, the origin and significance of religion and, last but not least, the origin of life. In these subjects are concentrated some of the profoundest problems which have ever tasked the intellectual power of man, problems the solutions of which, if they are ever reached eventually, must fundamentally affect human destiny, for that destiny, if it is to be one in which what we call progress is to participate, must ever be indissolubly associated with satisfaction of the cravings of the human intellect.

A few of the problems are cognate and, therefore, the solutions of some of these assist in the determination of the others. It is conceivable that the origin of matter and the extent of the universe are intimately related questions, and therefore, to advance towards certainty in one of them is to render less difficult the solution of the other. Further, the nature of the processes underlying thought is associated with the question of what life means on its physical side and the latter is in its turn intimately connected with the question of the origin of life. To conquer a solution in one case does more than facilitate a solution in another. It stimulates the human mind to greater effort. To the race of mountain climbers the conquest of one peak from which another of towering height may be seen, is not to daunt but to kindle an inscrutable ambition to dare and do in order that the climber may possess, for perhaps one rare moment only, the vision and the outlook from the new point of view far above the snow line.

The problem that appeared most difficult of all was the origin of life on the globe, nay the origin of life throughout the universe, if it be granted that the earth is not the only planet on which living forms have made their appearance or are màking their appearance. The difficulty

of the problem arose from the fact that little was known about the chemistry of the vital processes and even of the physical basis of life itself, that is, what has been commonly called protoplasm. Indeed the imagination was tasked to explain how a mixture called living matter could manifest the changes and transformations which are characteristic of life, the phenomena of assimilation, growth, reproduction and the transmission to the off-spring cells of the properties of the parent cells, the capacity to go on endlessly, if favorable environing conditions are maintained. These features of living matter have no counterpart in what is called dead or inorganic matter, and the gulf between the living and the non-living was not supposed to be bridged over by any means at the command of the thinker or the man of science. Is it any wonder that half a century ago when Darwin was writing his "Origin of Species" he should have used in the closing chapter of that work language which implied that he believed the one primordial form, from which all living things on this earth have had their origin, was called into existence by the direct act of a Creator? He laboured to show that all living forms arose from simpler forms in the past and that this evolutionary process is still going on and thus he accounted for the richly varied fauna and flora of the globe, but his mind evidently shrank from offering a solution of the question how the one parent form of all arose in the far distant past.

This was not, however, in every case the attitude of those who gave thought to the question. Twelve years after the publication of the "Origin of Species," that is in 1871, Lord Kelvin,* then Sir William Thomson, advanced the view that the impossibility of bringing about the conversion of lifeless into living matter without the aid of already living forms was as definitely established as is the law of gravitation and that consequently the only way to account for life on this planet was to suppose that it was originally borne by meteorites from outside the solar system. To this latter hypothesis he gave his full adhesion.

This theory did not receive general assent. It was recognized that even if living organisms could be so borne to our planet they would be destroyed by the intense heat generated when the meteorites began to penetrate the earth's atmosphere. Further the minimum amount of time required to transport such organisms on meteorites from the stellar system nearest to our own, namely that of α Centauri, would be about 62,000,000 years, and this at a speed of about 40 miles an hour and it would take nearly 140 years in going from Mars to the earth, at the same rate of speed. This length of time put the theory out of court,

*Presidential Address, British Association Meeting for 1871.

for organisms even under the most favorable conditions on our own planet have not in any case shown a capacity to remain germinative for more than a few years and consequently organisms which might arrive, meteorite-borne, from far distant stellar systems, even if they were not utterly destroyed by the intense heat generated at the moment of contact with the earth's atmosphere, would be utterly sterile.

This theory of the origin of life on the globe, now known as Panspermia, as already stated, did not receive general support and it would have perhaps in all discussions of the subject been deserving only of a reference had it not been revived in another form in 1903 by Arrhenius, the Swedish Chemist,* who employed the recently discovered fact of the pressure exercised by light and other radiations to show that organisms could be driven through space independently of meteorites and at a velocity enormously greater than the latter manifest. The pressure exerted by these radiations would, according to Arrhenius' calculations reduce the time for the transportation of organisms from α Centauri from 62,000,000 years to 9,000 years and from Mars to Earth to twenty days.

The greatest difficulty in the way of accepting the hypothesis of Panspermia is not the great length of time, shortened as it is by the motive power of the radiations, but the intense cold and light to which the organisms would be subjected in their course through space, but Arrhenius holds that this difficulty does not obtain. He cites the observations made by Duclaux on *Typothrix scaber*, an organism which occurs in milk and which is capable of undergoing a month's exposure to bright sunlight without injury and Roux has shown that the organisms causing splenic fever are not injured by bright light when they are kept in a vacuum. From this it would appear that oxygen must be present in order that light shall injuriously affect bacteria.

Intense cold, Arrhenius points out, does not necessarily act injuriously on all germs. Macfayden kept spores of bacteria at -200° C. for two months without affecting them appreciably. The intense degree of cold should not be destructive but preservative, for the diminution and, eventually, the loss of germinative power is certainly due to slow chemical changes, the rapidity of which is greatly diminished when the temperature is lowered. Thus in the case of vital processes which have been investigated, a fall of 10° C. reduces the speed of reaction to 2/5 and therefore, the rate of reaction responsible for the ultimate loss of vitality

*Arrhenius' views on Panspermia are given in "Das Werden der Welten" (trans. from the Swedish into German by L. Bamberger), Leipzig, 1907.

would proceed at –220° C., that is, the temperature of interstellar space, at one thousand millionth of the rate which obtains at 10° C., so that a journey of 3,000,000,000 years in space would be no more injurious in effect than one day's exposure to a spring temperature and sunlight on this planet. Inside of the solar system the temperature would be somewhat higher owing to the proximity of the sun, but the journey would be short and the microorganisms would survive.

The low temperature of interstellar space would reduce to a negligible minimum both photo-chemical changes and the rapidity of desiccation in the microorganisms on their journey. Schroeder has shown that *Pleurococcus* which grows on moist surfaces, as, for example, the bark of trees, and *Scenedesmus* whose normal medium is water, may be kept alive for twenty and sixteen weeks respectively, in a desiccator over concentrated sulphuric acid. Further, it is natural to suppose that desiccation, that is, evaporation, would be proportional to the vapour tension of water, which at –220° C., has not been directly measured, but can be computed approximately from the latent heat of evaporation by means of a formula given by van't Hoff and from it Arrhenius concludes that desiccation does not progress any farther in millions of years at –220° C., than in one day at 10° C. above zero.

The low temperature of interstellar space, therefore, reduces enormously in living matter the chemical changes that diminish vitality, the rapidity of photo-chemical changes and of desiccation and, in consequence, the life of microorganisms traversing interstellar space would be prolonged sufficiently to enable them to reach the earth and the other planets of the solar system in a condition to continue life and reproduce themselves in their new environment.

Arrhenius admits, however, that the organisms which thus arrive would in their first contact with the atmosphere of the earth encounter a temperature of notless than 100° C. due of course to that generated by friction. This he holds will not necessarily sterilize the organisms as protein, which is their physical basis, is not in the very dry state coagulated by such a high temperature, but it is exceedingly doubtful indeed if organisms which are supposed to retain in their long journey through space moisture enough to enable them to begin terrestrial life, would be profoundly unaffected by a temperature which ordinarily is germicidal.

There are in the main two objections to the Panspermic Theory. The first and chief is that it does not account in the last analysis for

the origin of life, but merely assumes that life began somewhere else in the universe, how and in what form it does not explain. The higher forms of life in that planet wherever it may be, if endowed not only with mental capacity like our own, but also with intellectual curiosity, would still have to account for their primal origin and it would not serve to say that the whole universe had been sown with life from their planet home. The burden which lies on those who believe in the Panspermic theory is to prove that life did not originate primarily on this globe.

If indeed the advocates of the Panspermic Theory were to claim that life has always existed since cosmic dawn and that the first living form was as much a directly creative act as the primal genesis of matter or of force, the position taken would in my opinion be a logical one, for the inscrutable agent that brought the universe into existence, might be supposed in that very act to have purposely endowed matter with a potency which in those primal conditions could not but have been realized.

The failure to postulate such a primal endowment and its result and the supposition that life had its origin on some planet in the universe, more or less like our own, predicate that origin elsewhere but do not explain it. He who believes that life throughout the universe had a community of origin may because of his theory be richer in poetic sentiment, but it does not help himself or others to formulate a satisfactory explanation of the primal origin of life either on this globe or elsewhere.

There is one objection to the Panspermic Theory which the biologist may advance. If terrestrial forms of life owe their origin to a form generated elsewhere, the latter must have been specially fitted to begin and continue life on this globe when its water contained nothing but inorganic salt and gases, such as nitrogen, oxygen and carbon dioxide, for such a form would have to assimilate not only carbon dioxide but also free nitrogen. The organisms upon the properties of which Arrhenius relies to show the possibility of forms surviving a long journey through interstellar space are all those of a highly specialized class, some of them capable of assimilating carbon dioxide, others of living only in media containing substances which are themselves the products of biochemical synthesis. None of these have the power of synthesizing their constituents out of wholly inorganic material including carbon dioxide and nitrogen. So far as yet known only certain of the Cyano-

phyceæ possess that power as Beijerinck* has pointed out and these, though primitive in their structure are of a so highly specialized vegetable character as to preclude their being considered as the forms from which both animal and vegetable organisms arose. Unless there were more than one form which reached the earth from far distant stellar systems, the organism which started life on the earth must have been very simple and neither animal nor vegetable definitely in its metabolic processes, in fact, in the latter respect like the Peridineæ which are also remarkable in that in them is found an exceedingly primitive type of nuclear division which, with their metabolism, indicates that they are very archebiontic in character. Whether they assimilate free nitrogen is not known.

It must be admitted that there are in the Panspermic Theory difficulties which are not overcome in explaining how the primal organism or organisms could reach the earth from far distant planetary systems, difficulties which are concerned in understanding how an organism itself of an indifferentiated character, even if it escaped destruction in transit, could find a terrestrial medium which would permit it to thrive and reproduce itself.

Because of these difficulties one turns to the theory of the origin of life on this planet which postulates that its first living form arose as the product of the action of physical and chemical forces on the constituents of the water and the atmosphere at a certain time in the history of the globe. This mode of origin is sometimes referred to as spontaneous generation but that name has so invidious a history and has been in the past associated with such extravagant speculations that it would perhaps be wise to abandon it and adopt another. It is further not a defensible name for in no sense can life be regarded as spontaneously produced on the globe to-day and the term "spontaneous" when used in this respect implies that living forms may arise *de novo* out of non-living matter at any time under the ordinary physical and chemical conditions which now obtain. The view so implied is not a defensible one as we shall see presently and it is well, therefore, to avoid the use of terminology which carries with it such an implication.

Aristotle was the first who definitely advanced the view that living organisms first arose spontaneously, but the view was held in a more or less inchoate form by the Greek philosophers from Thales onward. The poet, Lucretius, expressed this view when he said that "the earth

*M. W. Beijerinck—"Further Researches concerning Oligonitrophilous Microbes," Kon. Akad. van Wetensch., Proceedings, Vol. 4, p. 5, 1901-2.

has rightly received the name of mother since all things are begotten of it and many living creatures arise out of it, having been generated by the rains and the warm mists formed by the sun."*

From the time of Lucretius and till the nineteenth century the belief in the occurrence of spontaneous generation was almost universal and it was not an unnatural result of the observations which were made in an uncritical age. It was well known that when a quantity of tissue like beef-muscle is exposed to the free air and sunshine at summer temperature the larval forms of flies and other insects appear in it in a few days. The explanation of their appearance there was that they were spontaneously generated in the putrefying animal flesh. This explanation was everywhere excepted until Redi, in 1668, definitely showed that when meat is placed in a wide-mouth jar and the mouth covered with thin gauze so as to permit free entrance of air and warmth, but also so as to exclude flies, no larvæ made their appearance in the medium and thus the larvæ which ordinarily grew there were not due to any spontaneous generation but to the eggs deposited by flies.

These observations of Redi were conclusive so far as they went and gradually the instances where spontaneous generation was supposed to occur became fewer the more the microscope was employed to study the occurrence and characters of forms of life known as animalculæ. It was not, however, admitted on all hands that the minute organisms such as the microscope of the seventeenth and eighteenth century revealed to the investigator arose from pre-existing forms and this view was stoutly maintained by Needham and Buffon. Needham found that when he heated infusions of animal or vegetable material in carefully corked vessels to such a temperature as would destroy germs existing in the infusions, the latter kept for a few days at the temperature of the room were found to swarm with animalculæ and therefore the latter must have arisen from matter which was not alive. This work was repeated by Buffon and Needham's results were corroborated.

It was, however, pointed out by Spallanzani that Needham's and Buffon's conclusion did not follow from their results. He found that if the infusions were heated for half an hour or more in glass vessels hermetically sealed by fusing their necks in the flame, no animalculæ

* "Linquitur ut merito maternum nomen adepta
Terra sit, e terra quoniam sunt cuncta creata.
Multaque nunc etiam exsistant animalia terris,
Imbribus et calido solis concreta vapore."
—De Rerum Natura, Lib. V. 793-796.

ever appeared in them so long as they were contained in such air-excluding vessels.

The discovery of oxygen and its properties led those who accepted spontaneous generation to claim that in these experiments of Spallanzani and others, one of the most necessary factors, namely oxygen, was excluded, and thus their results did not confute the idea of spontaneous generation. The discussion on the subject went on on this basis through the early years of the last century but it was closed only on the publication of the results of Schroeder and Dusch in 1854 and of Schroeder in 1859. These observers found that when, instead of hermetically sealing by fusion the necks of the vessels containing infusions of animal or vegetable matter, the mouths were closed with plugs of cotton wool, the infusions, which were heated as in Spallanzani's experiment, did not subsequently contain animalculæ, although the oxygen, but not the organisms, of the atmosphere gained ready entrance to the medium through the cotton wool.

The net result of the investigations of the last half-century has been to show that living matter does not originate spontaneously under any condition which obtains on the globe to-day, nor can it be granted that it may arise spontaneously in any culture medium however favorable the latter may be to the generation of living forms *de novo*. It is necessary to be thus explicit for otherwise I might be understood as accepting views which are still advanced in certain quarters, but which seem to me to be utterly untenable.

To repudiate spontaneous generation and to believe that a living form did at one time in the history of the globe arise from non-living matter are two very distinct positions to take and yet I accept them both as tenable. It is not necessary to defend the first for I have already said enough to that end. The second position is practically that already taken by biologists generally. Huxley, whose address as President of the British Association for 1870 was a crushing refutation of the doctrine of spontaneous generation, practically endorsed that position in language which will bear repetition here. After indicating his inability to hold any belief as to the primal origin of life he went on to say :—
"But expectation is permissible where belief is not, and if it were given me to look beyond the abyss of geologically recorded time to the still more remote period when the earth was passing through physical and chemical conditions, which it can no more see again than a man can recall his infancy, I should expect to see it appear under forms of great

simplicity, endowed like existing fungi with power of determining the formation of new protoplasms from such matters as ammonium carbonates, oxalates and tartrates, alkaline and earthy phosphates and water without the aid of light."

The greatest difficulty experienced in attempting to account for the origin of life on the globe as a result of physical and chemical conditions has always been found in the complexity of the molecules of the proteins which enter into the composition of protoplasm, the physical basis of life. Forty, thirty, and even ten years ago the constitution of protein seemed an insoluble riddle. Proteins are undoubtedly the most complicated compounds known to the chemist. The latter has been able to determine the composition of as many as one hundred thousand organic compounds, that is, apart from proteins, the whole range of organic compounds, but he was unable till recently not only to synthesize the simplest protein derivatives but also to have even a faint conception of what atom groups the protein molecule is composed.

The work of Kossel and his school gave the first light on the problem. By means of hydrolysis with dilute mineral acids the protein molecule was shown to be largely constituted of amino acids, acids in the majority of cases belonging to the "fatty" series with one of the hydrogens of one or more alkyl groups replaced by NH_2 and thus giving bodies each of which is at the same time both an acid and a base. The simplest of these amino-acids is known as amino-acetic acid which is constituted thus :—

$$CH_2(NH)_2.\ COOH$$

This is one of the most abundant constituent atom-groups of the molecule of gelatine. The next higher amino-acid is α-amino-propionic acid which is commonly called alanine and which has the following constitution :—

$$CH_3.\ CH(NH_2)\ COOH$$

There are a large number of others, the more important of which are cysteine or α-amino-β-thio-propionic acid :—

$$CH_2(SH).\ CH(NH_2).\ COOH\ ;$$

Valine or α-amino isovalerianic acid,

$$\left.\begin{matrix} CH_3 \\ CH_3 \end{matrix}\right\rangle CH.\ CH(NH_2).\ COOH\ ;$$

Leucine or α-amino-isobutylacetic acid,

$$\begin{matrix}CH_3\\CH_3\end{matrix}\!\!\rangle\, CH.\, CH_2.\, CH(NH_2).\, COOH\,;$$

Arginine, or δ-guanidin-α-amino-valerianic acid,

$$\begin{matrix}NH_2 & & & & & & NH_2\\ | & & & & & & |\\ NH{=}C{-}NH & CH_2. & CH_2. & CH_2. & CH. & COOH\,;\end{matrix}$$

Histidine, or β-imidoazol-α-amino-propionic acid,

$$\begin{matrix}CH-NH\\ \|\quad\quad\rangle CH\\ C\,-\,N\\ |\\ CH_2\\ |\\ CHNH\\ |\\ COOH\,;\end{matrix}$$

Lysine or α-ε diamino-caproic acid,

$$\begin{matrix}NH_2 & & & & NH_2\\ | & & & & |\\ CH_2. & CH_2. & CH_2. & CH_2. & CH.\ COOH.\end{matrix}$$

The presence of these and other amino-acids in the protein molecule is highly significant. If we regard the molecule as a building or edifice then these amino-acids are the building stones and the character of the molecule must depend on the amino groups which constitute it just as the character of the building depends on the building material used.

The occurrence of methyl groups places the relation of the proteins to the fats and carbohydrates in a very clear light. It indicates that after all the distinction between proteins on the one hand and fats and carbohydrates on the other is not a radical one and that the framework of the molecules in all three classes of compounds is fundamentally the same, namely, a chain of alkyl radicles arranged in series and groups more or less individualized in the chain. The highest number of alkyl radicles in a single group is that found in diamino-trioxy-dodecanic acid, $C_{12}H_{26}N_2O_5$, of which there are small quantities found in certain of the proteins but the most common groups are those which have less than six alkyl radicles.

In addition to the alkyl radicles there are those of benzene and indol as, for example, in tyrosine and tryptophane. These appear to be associated with the alkyl radicles but they constitute only a small percentage of the total protein molecule.

The work of Kossel and his pupils was paralleled by that of Emil Fischer. The latter devoted his energies to the synthesis of proteins in the laboratory and the success which he has achieved so far in his efforts has been such as to make it possible to hope that the synthesis of protein is a matter now of a few years' steady experiment and investigation. The compounds synthesized contain atom-groups formed of the amino-acids and because a majority give one of the reactions peculiar to peptones he has termed them peptides. The method upon which he has proceeded is to allow an acid chloride of a halogen fatty acid to act on an amino-acid as indicated in the following equation :—

$CH_2\,Cl.\,COCl + NH_2\,CH.\,COOH =$

$$CH_2\,Cl\,CONH.\,CH_2\,COOH + HCl.$$

The resulting product is then made to react with ammonia thus :—

$CH_2\,Cl\,CO.\,NH\,CH_2\,COOH + NH_3 =$

$$CH_2\,NH_2\,CO.\,NH\,CH_2.\,COOH + HCl.$$

The compound produced which is called glycyl-glycin can itself be converted into a chlorinated compound and that acting on glycin gives a peptide holding three amino-atom-groups :—

$$CH_2\,NH_2\,CO.\,NH\,CH_2\,CO.\,NH\,CH_2\,COOH.$$

The compound formed is diglycylglycin.

The syntheses of peptides have been effected by Fischer and his students in over one hundred cases and the largest number of amino acid radicals synthesized in the one nolecule as yet is eighteen with a molecular weight of 1213 but this suffices to show that the method employed is one by which the synthesis of protein from simpler compounds is ultimately to be accomplished. That the peptides formed by Fischer do, in the main, not differ from peptones in the manner in which their atom groups are combined is shown by the fact that trypsin, the digestive ferment, breaks a number of them up into the simple amino-acids just as this ferment does in the case of the peptones. That there is any difference at all between the more complex peptides thus formed and the peptones themselves is due to the character as well as

the number of atom-groups forming part of the chain and it is, therefore, not inconceivable that having determined how many examples of each there is in the peptone chain, the artificial production of the latter in the laboratory may soon be effected. The production of peptones in this manner would lead eventually to the synthesis from them of proteins.

The results achieved so far show that the constitution of proteins is no longer an insoluble mystery and that their manufacture in the laboratory is not an impossible event. The presence of these amino-acid radicals in vegetable as well as in animal proteins indicates that biochemical synthesis proceeds in the same way in both kingdoms and that practically the same construction material is used. As proteins are the material of which the material basis of life is constituted it is manifest that if we could explain how proteins first arose without the participation of living matter in the synthetic act we might be in a position to explain the origin of living matter itself.

The simplest proteins that we know are protamines which are found in the heads of the sperm cells of fishes and united there with a special compound of phosphorus known as nucleic acid. The compound in the heads of the sperm cells is responsible for the functions the sperm cells perform and it is the physical basis of the life of the sperm element. Some of these protamines are constituted of diamino acids only and are thus practically compounds intermediate between peptides and proteins but their chief significance is that they show that complex vital processes can function in such comparatively simple compounds, that is, the molecular constitution with which vital processes are associated may be of a comparatively simple kind.

The simplest proteins, that is, protamines, as well as the most complicated and highly organized proteins do not form true solutions with water but rather what is known as colloidal suspensions, suspensions, however, in which the particles suspended or held in the fluid are of so minute a size that they cannot be seen with the highest powers of the microscope. The limit of microscopic vision is about 0.14 of a micron, that is, of one thousandth of a millimetre. An object more minute than that or under one-one hundred and seventy-five thousandth part of an inch cannot be seen. To have, therefore, any evidence, that in solutions of proteins the latter are in the form of suspended particles one must employ the ultramicroscope, that is, a modification of the microscope which will reveal the presence of such particles in practically

the same manner as particles of dust which float in the path of a sunbeam are revealed. If one were to stand in the course of a sunbeam and look toward the source of the light, namely the sun, no floating dust particles would be seen but if one stands aside in the dimly lighted room and looks at the beam the dust particles come out very clearly, for the light which is reflected from the numerous facies of each comes to the eyes as divergent rays and the dust particles are thus seen greatly magnified. Quite so in the ultramicroscope the light instead of coming from the reflector under the microscope straight through the microscope to the eye, is sent obliquely through the object, which in this case is a drop of colloid solution, the particles in suspension of which scatter the light as the dust particles do in the sunbeam and in consequence some of the divergent rays passing up the tube of the microscope and reaching the eye reveal the particles as greatly magnified flashing points of light. In fact the particles in such a case set against the dark background of the field appear like as if they were bright stars set in the cloudless, moonless night sky.

The ultramicroscope will not reveal the presence of particles less in diameter than one-hundredth of a micron, that is, less than one-two million five hundred thousandth part of an inch, so that the limits of ultramicroscopic vision are 1/7 and 1/100 of a micron. What their true measurement may be in the case of protein solutions we do not know but Mr. E. F. Burton* has, by an ingenious method, determined that the suspension particles of colloidal solutions of gold, platinum and silver have a diameter which ranges between 2/100 and 6/100 of a micron. It is not unlikely that these represent also the limits in the diameter of the particles in protein suspension solutions.

Now the significance of these particles comes out strikingly when it is recognized that protoplasm is constituted of myriads of such suspension particles of protein closely packed together and that the properties of living matter, that is, protoplasm, are the properties also of each suspension particle present in it. Each particle in protoplasm is in a definite sense alive just as is the protoplasm as a whole and consequently though it may not continue to live after its separation and isolation from its fellows because there has developed amongst them an interdependance, it is conceivable that ultramicroscopic particles consisting of but a few molecules of protein appropriately constituted could live separately and reproduce themselves by division when the particles had grown beyond a certain size.

*Phil. Mag., Vol. (6), II, p. 425, 1905.

That such ultramicroscopic forms of life exist we know in a few cases at least. Beijerinck in his study of the disease of tobacco leaf found that the causative element could not be seen with the highest powers of the microscope and that it was minute enough to pass through the pores of a Chamberland filter. That the disease is due to a micro-organism and not a ferment other facts determine beyond doubt. Further, the consensus of opinion amongst those who have carefully investigated the question is that yellow fever is due to a micro organism which is ultramicroscopic and it is possible that the pathogenic agent in rabies is also an organism that is beyond the limits of microscopic vision.

It is not necessary to multiply instance, it suffices for our present purpose to note that there are to-day organisms which consist practically of suspension particles constituted of a few molecules aggregated as in the case of each protein particle in suspension in a "solution" of white of egg, and that these molecules in each single isolated particle carry on the functions which we usually group under those of life.

When in consequence we seek to explain the origin of life, we do not require to postulate a highly complex organism such as we can see even with the low power of the microscope, as being the primal parent of all, but rather one which consists of a few molecules only and of such a size that it is beyond the limits of vision with the highest powers of the microscope. Such an organism would be the smallest unit of life and it might be supposed that protoplasm arose from aggregation of such units, each more or less differentiated from its fellows, just as the higher or multicellular forms of life have arisen by aggregation of cells which have differentiated more or less, thus giving rise to differences of function in the different parts.

The question which we now must face is this:—Did conditions ever exist in the history of the globe which favoured the production by natural means of such ultramicroscopic organisms? The answer which I would make to this question is an affirmative one.

According to the Nebular Theory a great many constituents of the rock crust of the globe such as carbon monoxide, carbon dioxide, chlorine, phosphorus as phosphoric pentoxide, sulphur as sulphur dioxide and trioxide, potassium, sodium, calcium, magnesium, as well as all the water on the globe, were, when the earth was cooling down from 1200° C. to 900° C., in the atmosphere, the pressure of which on calculation was greatly over 270 times that of our atmosphere. As the temperature

sank below 900° C., the sulphur dioxide, and trioxide, the phosphorus as phosphates and the sodium, potassium, calcium and magnesium compounds condensed and there remained in the atmosphere water vapour, oxygen, nitrogen, chlorine, carbon dioxide and carbon monoxide which left the pressure of the atmosphere about 270 times what it is now. When the temperature fell to 350° C. condensation took place until only a pressure of 190 atmospheres mained and as it fell lower still further condensation occurred and a further reduction of pressure obtained but it must at least have been 30 times the present pressure when the temperature was about 120° C. In this enormous pressure there must have been countless condensations and the water condensed must as often have boiled away from the hot rock crust as soon as deposition occurred. As these condensations were obtaining in the high pressure atmosphere there must have been electrical discharges of enormous voltage which would cause the formation of ammonia, and as carbonyl chloride must have been present urea must have been formed. There must have been present also in the atmosphere hydrocarbons of all kinds for the action of water on the hot rock crust must have formed them from the metallic carbides such as carbide of iron and of calcium, as probably happens to-day also in the production of petroleum compounds in connection with hot subterranean rocks. Since the temperature was high the hydrocarbons, being volatilizable, diffused in the atmosphere and in conjunction with chlorine vapour, carbonyl chloride and carbon dioxide innumerable syntheses would occur, many of them being of the chain type and with the carbon dioxide the carbonyl chloride and the ammonia present amino-acids would be formed, especially when the temperature sank below 100° C. The amino acids would also occur in the chlorinated condition which would facilitate, as in the laboratory, synthesis of polypeptides and as these would obtain in the condensations of aqueous vapor the synthesis of proteins from the polypeptides would occur in the chlorine-containing water.

This formation of amino acids and their synthesis to form proteins would take place countless millions of times and in every variety of constitution until one giving the right composition resulted in ultramicroscopic particles which, endowed with the chemical properties of ultramicroscopic organisms, would thrive and reproduce themselves in water which contained amino-acids and which would thus supply readily assimilable food to the newly formed living structures.

Just at what temperature such a synthesis and such an origin of ultramicroscopic organisms occurred it is difficult to say but it is possible

that it may have been about or slightly above 80° C. We are so accustomed to think of living forms being destroyed at a temperature above 75° C. that we are not prepared to believe that a higher temperature would leave unaffected living forms of a simple chemical constitution, but that is because we attribute to all living forms a complex chemical constitution which is easily affected by high temperatures. It is not inconceivable that of the forms of life we know even the simplest are highly complex and thus we cannot bring ourselves to understand that living forms may exist or could have existed which possess or possessed only a tithe of the properties which we attribute to living forms. With the simpler constitution temperatures somewhat above 80° C. may have been harmless in their effect on such ultramicroscopic organisms as may have first arisen.

Once arisen the forms would continue and reproduce themselves just as the ultramicroscopic particles in living matter increase in size and reproduce themselves by division in order that there may be additions to the protoplasm such as growth demands. It may be that countless forms of ultramicroscopic organisms developed and vanished before one arose endowed with the constitution and properties which would enable it to survive through all the physical conditions attendant upon its origin. Such a form once brought into being would start on its long career, out of it would develop the protoplasmic mass just visible under the highest powers of the microscope and gradually but eventually from that again the living cell, the parent form of all structures such as we ordinarily recognize as animal and vegetable organisms.

It may be objected that this explanation of the origin of life on the globe is based on conditions postulated by the Nebular Theory and that such high temperatures did not obtain if the earth was formed in the manner demanded by the Planetesimal Theory, as advanced by Chamberlin. In answer to this objection it may be said that the Planetesimal Theory does not exclude the occurrence of gaseous, molten and high temperature stages in the earth's history. Chamberlin admits that the infalls of the planetesimals to form the earth would result in high temperatures, in volatilization of many constituents of the present solid globe and that the present high temperature in the earth's interior which is assumed to be about 20,000° C. may have been inherited from an earlier stage. Further, according to Chamberlin the hydrospheres first appeared when the earth had half its present diameter, that is when it was no larger than Mars is now.

As to the temperature preceeding this period of development, Chamberlin is not quite certain, for his language is as follows:—*

"There was, however, a terrestrial source of heat and light of critical importance, namely, that arising from the infall of the planetesimals. If this infall were at a rate sufficient to heat the surface of the earth above 100° C. life of the present types would have been prohibited. The present stage of the inquiry does not permit any very confident opinion as to whether this excess was reached or not. Leaving this question open, it is to be noted that if, at the stage when an atmosphere and hydrosphere could be held, the infall of planetesimals was so rapid as to heat the surface to a prohibitive temperature, the rate of infall must almost certainly have declined as the number of planetesimals in the earth's feeding zone was diminished so that, long before the supply was exhausted and growth ceased, the rate must inevitably have fallen below the prohibitive limit. If, therefore, the earth were too hot for life when one-fifth grown, its temperature might have become suitably mild when one-fourth, one-third, one-half, or three-fourths grown. Growth after this permissive stage was reached would be slow and the period required for its completion would still be long."

It is obvious therefore, that even the Planetesimal Theory does not negative the view that high temperatures did obtain in the earth's atmosphere before a hydrosphere was formed or even after one was developed, and that the conditions which would obtain, on the basis of the Nebular Theory, as favorable to the origin of life, would obtain in the planetesimal development of the earth.

Just at what period in the earth's history these conditions obtained it is not now possible to say. We know that highly developed forms like *Olenellus*, forms quite as highly developed and specialized as vertebrates, appeared in the early Cambrian Period, and therefore, the development of such highly specialized forms must have begun at a vastly earlier stage. But back of all this is a period incalculably longer, a period during which the cell was specializing into animal and vegetable types and back still of that period was another of still greater duration which was required to develop in the cell, still neither animal nor vegetable definitely, those peculiar processes which the animal as well as the vegetable cell now manifests when it undergoes what is known as cell division.

To have fixed in the cell, animal and vegetable, those mitotic

* Carnegie Institution Year Book, No. 3, 1905, p. 250.

processes so that they should not have altered in all the subsequent geological eras must have required an inconceivably long period of time.

Still very much farther back must have been the date when life originated as ultramicroscopic organisms, for out of such eventually developed the cell.

The biologist, and more particularly the cytologist, reviewing these matters, is inclined to regard the length of time during which stratified rocks, including those of the Huronian Age, were laid down as but a small fraction of that which has passed since the origin of life on the earth. The geologist may perhaps not share this view, but the facts which the cytologist has ascertained are of such a character as to compel him to recognize that a period of enormous length must have intervened between the time when life first began on the globe and the time when the differentiation of the primal cell into animal and vegetable types commenced.

In closing it may be pointed out what the explanation here advanced concerning the origin of life on this globe involves. It follows, almost inevitably, that as every planet in every stellar system has passed or is passing through the same history as the earth has known, the same physical conditions have given or are now giving the same result or will ultimately do so and of course life cannot then be considered as confined to the earth only. How vast the universe may be we do not know and whether there is any limit to it we cannot say. Kapteyn* of Gröningen has from his studies on star drift advanced the view that there are two visible universes travelling in opposite directions in space. His observations and views have received the support of astronomers generally. It is conceivable that far beyond the penetration of the most efficient telescope, that is, beyond what Lucretius calls *flammantia mœnia mundi,* "the flaming ramparts of the world," there are other universes, perhaps countless in number, each with its history repeating that of our own. We do not, however, require to postulate that the depth of space is strewn with universes in order to realize the magnitude of the destiny of life. It is estimated that there are at least 300,000 suns visible in space and each of these probably has its own planetary system. On 2,000,000 planets then the story of the origin of life on earth, herein outlined, has been, is now being, or is to be, repeated and thus there is an eternal procession of life throughout the universe. There is another thought that results from this explanation of the origin of life and from

* "Star Streaming," British Association Report, 1905, p. 257.

its consideration as valid for the whole universe. No one, I think, can survey the subject without being impelled to believe that behind it all there is a vast destiny, feebly named a purpose, inscrutable perhaps to our finite intelligence, but still a destiny, an end to which all things are proceeding.

CRYSTALLIZATION OF ERYTHRITE FROM COBALT.

By W. F. Green, M.A.,
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(*Read 6th March, 1909*).

Erythrite, or Cobalt Bloom, as it is commonly known, has considerable interest connected with it, as it was the pink stain on the rocks that was associated with the first discovery of the mines in the famous Cobalt district. The Bloom found generally in the veins is the earthy variety and seldom shows good crystallization. Through the kindness of Messrs. J. W. Bain and A. L. Parsons, of the University of Toronto, I procured a specimen of well crystallized Erythrite. From this specimen were obtained a few crystals which were mounted and measured on a Goldschmidt two circle goniometer, to which method of measuring the appended numbers refer.

The crystals occur in the form of a druse and are attached to the matrix by one end of the vertical axis. They are small and when examined closely most of them are found to be a growth of thinner crystals in approximate parallel position.

Elements.

The axial ratio and the angle β are given by Goldschmidt in his Winkeltabellen for the Schneeberg crystals. The elements obtained from the Cobalt crystals are:—

$$a : b : c :: 0.7502 : 1 : 0.7006 \qquad \beta = 105°\text{–}01'$$

as compared with

$$a : b : c :: 0.75 : 1 : 0.70 \qquad \beta = 105°\text{–}00'$$

cited in Goldschmidt's Winkeltabellen.

Forms.

In all, seven forms were observed of which four are given in Goldschmidt's Tabellen and a fifth ≷100≷ in Dana's System of Mineralogy. The two new forms observed on the crystals examined are ≷104≷ a very persistent large rough face and ≷350≷ which occurs very plainly

on one crystal as fairly broad bands. This form was observed in all four quadrants.

NEW FORMS.

Of the two new forms observed one is in the prismatic zone and the other a terminal face.

∞ 5/3, $\lessgtr$350$\gtrless$. This is a broad face in the prismatic zone giving a bright reflection and a fair image.

	φ	ϱ
Measured	39° –34′	90° –00′
Calculated	39° –38′	90° –00′

+¼0, $\lessgtr$104$\gtrless$. This is a large, rough face giving no image, the readings being the observed maximum lustre.

	φ	ϱ
Measured	90° –00′	27° –00′
Calculated	90° –00′	27° –01′

About a dozen crystals were measured, the results submitted having reference to the six best crystals.

The total result in crystal forms may be summarized thus:—

Letters.	Symbols.		Number of crystals on which found.
	Goldschmidt.	Miller.	
b	0 ∞	010	6
m	∞	110	3
w	–10	$\bar{1}01$	6
v	–1	$\bar{1}11$	6
a	∞ 0	100	2
x	∞ 5/3	350	1
y	+ ¼ 0	104	6

Individually the six crystals present the following forms in combination:

Crystal.	Forms present.
1	b, v, w, y
2	b, m, w, v, y
3	b, w, v, y
4	b, m, w, v, y
5	b, m, w, v, a, x, y
6	b, w, v, a, y

CRYSTAL HABIT.

Only one habit was observed in these crystals. They are characterized by broad, side pinacoids ≷010≷, a large rough negative hemi-orthodome ≷104≷, a small bright, positive hemi-orthodome ≷$\bar{1}$01≷ and the positive hemi-pyramids ≷$\bar{1}$11≷. The prismatic faces are frequently striated.

For comparison several crystals from the Schneeberg region were examined. These crystals are characterized by the occurrence of the positive hemi-pyramids ≷$\bar{1}$11≷ and the positive hemi-orthodome ≷$\bar{1}$01≷. Other terminal faces were not observed. In the Schneeberg crystals, as in those from Cobalt, the pinacoid ≷010≷ is the most highly developed crystal form.

The habit of crystal 5 is represented in the drawing on Plate No. 1.

The instrument with which these readings were made is a two circle reflecting goniometer of the Goldschmidt model. This, together with instruction in the calculation and gnomonic projection of the forms based on these measurements have been described by Goldschmidt* and also by Palache.†

In the monoclinic system the formulæ for obtaining the elements from the readings φ and ϱ on the vertical and horizontal circles are:—

$$x' = \sin \varphi \tan \varrho. \qquad y' = \cos \varphi \tan \varrho.$$

where x′ and y′ are the rectangular co-ordinates of the point. A

*Goldschmidt:—Goniometer mit zwei Kreisen, Zeitschrift für Krystallographie 1893, 21, 210-232. Die zweikreisige Goniometer (Modell 1896) und seine Justierung Idem 1898, 29, 333-345.

†Charles Palache:—On Crystal Measurements by means of Angular Co-ordinates and on the use of the Goniometer with two circles. American Journal of Science 1896 (4), 2, 298.

gnomonic projection was made and each face was plotted by means of values of φ and ϱ as measured. The symbols for the different faces were then determined graphically. The symbols for the different faces may also be calculated from the angular co-ordinates x′ and y′. Thus:—

$$x' = pp_o' + e', \qquad y' = qq_o', \qquad e' = \cot \mu.$$

where the symbols p and q are simple multiples or sub-multiples of the co-ordinates p_o' and q_o' of the unit form $\lesssim 111 \gtrsim$ and e′ is the tangent of the angle the base normal makes with the pole.

These formulæ hold for terminal faces but for prisms we have,

$$x' = \sin \varphi \tan \varrho, \qquad y' = \cos \varphi \tan \varrho,$$

whence it follows $\frac{x'}{y'} = \frac{\sin \varphi}{\cos \varphi} = \tan \varphi$.

For positive faces on the projection $pp_o' = x' - e'$.

For negative faces on the projection $pp_o' = x' + e'$.

The unit form selected is the pyramid $\lesssim \bar{1}11 \gtrsim$. Since all the good bright forms are negative the value of q_o' must be obtained from the unit form and this value substituted in the values obtained from the formulæ for the prisms.

q_o'
0.6983
0.7065
0.6985
0.6995
0.7003
0.7006 = average q_o' for five readings.

p_o'
0.9712
0.9714
0.9673
0.9656
0.9667
0.9600
0.9670 = average p_o' for six readings.

The elements for Erythrite then become,

$p_o' = 0.9670$, $q_o' = 0.7006$, $e' = 0.2681$, $\mu = 74^\circ - 59'$.

POLAR ELEMENTS p_o, q_o, AND e.

p_o', q_o', and e′ are the elements when $h=1$. With $r_o=1$ we have $h=\sin\mu$ so if the elements p_o', q_o', and e′ be multiplied by $\sin\mu$ we have the polar elements p_o, q_o, and e., *i.e.*, $p_o=p_o'\sin\mu$, $q_o=q_o'\sin\mu$, $e=e'\sin\mu$, therefore the polar elements are:

$$p_o=0.9339, \qquad q_o=0.6766, \qquad e=0.2591.$$

The axial lengths and the angle β are obtained from the elements thus:—

$$a=\frac{q_o'}{p_o}=\frac{q_o}{p_o\sin\mu} \qquad c=\frac{q_o}{\sin\mu}=q_o', \qquad \beta=180°-\mu.$$

By substituting in these equations the values of the elements determined we have $a=0.7502$ and $c=0.7006$ and the axial ratio for Erythrite becomes:—

$$a : 1 : c :: 0.7502 : 1 : 0.7006.$$

As an example, the following records on crystal 5 are given as they appear in the note book

Reflection.	No. of Face,	V	H	φ	ϱ	Prisms=tan φ			$pp_o'=x'-e'$ for positive, $pp_o'=x'+e'$ for negative.	qq'	Symbols.	Remarks.
						log sin φ " tan ϱ " cos φ	log x' " y'	x' y'				
Good	1	148-58	320-00	0-04	90-00	.....	....	.....	.....	.....	$\bar{0}10$	
Fair	2	329-06	320-00	0-04	90-00	.....	.....	.....	.....	.....	010	
Poor	3	239-01	320-00	89-59	90-00	.....	.....	.....	.....	.....	$\bar{1}00$	
No image	4	59-25	320-00	89-37	90-00	....	.....	.....	....	....	100	Best reflection
Good	5	284-11	274-34	44-51	44-34	9.84834 9.99343 9.85062	9.84177 9.84405	0.69466 0.69832	....	0.69832	$\bar{1}11$	
Good	6	193-53	274-54	44-51	44-54	9.84834 9.99848 9.85062	9.84682 9.84910	0.70279 0.70649	.....	0.7064	$\bar{1}11$	
Poor	7	23-00	320-00	53-58	90-00	.....	....	1.3746	....	.....	110	
Poor	8	94-23	320-00	54-39	90-00	.....	....	1.4097	....	....	$\bar{1}10$	
Fair	9	203-05	320-00	54-03	90-00	.....	.....	1.3789	.....	.....	$\bar{1}10$	
Good	10	275-11	320-00	53-51	90-00	.....	.....	1.3688	.....	....	$\bar{1}10$	
Fair	11	289-30	319-58	39-32	89-58	....	....	0.8253	.....	.....	$\bar{3}50$	
Fair	12	188-36	320-00	39-34	.....	.....	.....	0.8263	....	.....	$\bar{3}50$	
Poor	13	109-18	320-00	39-44	90-00	.....	.....	0.8312	.....	.....	$\bar{3}50$	
Fair	14	8-56	319-57	39-54	90-00	... .	....	0.8361	... ...	.....	350	
No image	15	59-00	257-00	89-58	27-00	9.70716	9.70716	0.5095	0.5095	0	104	Maximum lustre

The Winkeltabellen for all the forms observed calculated from the elements obtained from Cobalt crystals is as follows :—

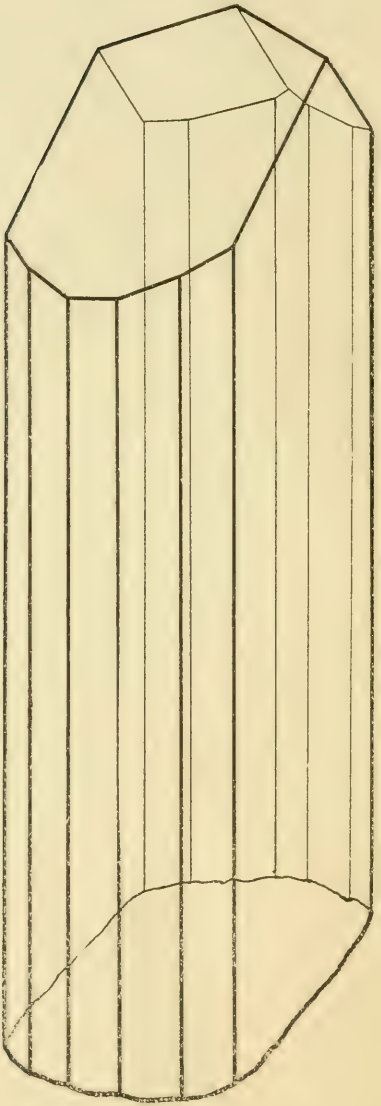
ERYTHRITE.

$a = 0.7502$	$Lga = 987517$	$Lga_o = 002978$	$Lgp_o = 997030$	$a_o = 1.071$	$p_o = 0.9339$
$c = 0.7006$	$Lgc = 984547$	$Lgb_o = 015442$	$Lgq_o = 983033$	$b_o = 1.427$	$q_o = 0.6766$
$\mu =$ $180 - \beta = 74 - 59$	$Lgh =$ $Lg \sin \mu = 998491$	$Lge =$ $Lg \cos \mu = 941346$	$Lg\frac{p_o}{q_o} = 013990$	$h = 0.9658$	$e = 0.2591$

Number.	Letter.	Symbol. Gold-sch'dt	Symbol. Miller.	φ	ϱ	ξ_o	η_o	ξ	η	x′ prism(x:y)	y′	d′ $= \tan \varrho$
1	b	$0\,\infty$	010	00-00	90-00	00-00	90-00	00-00	90-00	0	∞	∞
2	a	$\infty\,0$	100	90-00	90-00	90-00	00-00	90-00	00-00	∞	0	∞
3	m	∞	110	54-05	90-00	90-00	90-00	54-05	35-55	1.3804	∞	∞
4	x	$\infty\,5/3$	350	39-38	90-00	90-00	90-00	39-38	50-22	0.8286	∞	∞
5	w	-10	$\bar{1}01$	90-00	34-55	$\bar{3}4$-55	00-00	34-55	00-00	0.6983	0.	0.6983
6	y	$+\frac{1}{4}0$	104	90-00	27-00	27-00	00-00	27-00	00-00	0.5095	0.	0.5095
7	v	-1	$\bar{1}11$	44-55	44-40	$\bar{3}4$-55	35-00	$\bar{2}9$-46	29-51	0.6983	0.7006	0.9887

In conclusion I wish to thank Dr. T. L. Walker for the interest taken and the assistance given in this work.

PLATE NO. I.



ERYTHRITE

A NEBULAR THEORY OF CREATION.

By G. G. Pursey.

(*Read 21st March*, 1908).

The subject which I have presumed to take up and discuss for a little while this evening is of far reaching scope, and almost bewildering magnitude. Nothing less than the formation, preparation, and equipment of a world to give birth and sustenance to teeming millions of life forms, conceived in its secret chambers, and nourished on its broad bosom through unnumbered ages. A work, or process, requiring a period of time of incalculable duration, reckoned, if it can be reckoned at all, by thousands of millions of our little years.

I shall have occasion perhaps in tracing the antenatal history of the earth as it may be called—to go back of Laplace or any others, so far as I am aware, who have ventured upon this absorbing field of speculative science.

Before entering into the subject proper, I wish to state a few general principles to prepare the ground for what follows, and remove the need for explanations as I proceed. Matter, we must postulate, worlds cannot be made without it, and there is any amount ready to hand. How, or when matter came into existence must remain an unsolved problem. But of the changes which matter undergoes, and of its adaptability to be moulded into infinite forms, we do know a little, but of the law of forms, we must acknowledge that we know almost nothing, and it has been said that "we have no doctrine of forms in our Philosophy."

Experience has taught us that all forms are unstable, that no material form endures, and so far as we know, this law is written upon everything we see in the physical world. And further, science has all but demonstrated that the entire universe is made of one stuff. Hence we infer it will be subject to and controlled by somewhat similar general-laws, though it may be under infinitely diverse conditions. And so we find running through all the kingdoms of nature, birth—or a beginning corresponding to birth, growth, maturity, gestation, parturition, or procreation, decay, death, and dissolution. This appears to be the common lot of all mundane things, and throughout the life history of animal, vegetable or mineral

there is a continual tug of war between two opposing forces—the vital force or life principle versus the chemical or destructive principle, the one always in the effort to build up and maintain intact, the other just as industriously engaged in pulling down and disintegrating. From birth to maturity the vital force dominates, in normal conditions. In mature life the forces are about equal. In old age the chemical prevails and finally overcomes in the unequal contest, and organized bodies we say die, but eventually "the great globe itself with all that it inherits will dissolve." In fact life and death would seem to be the opposite poles or the to and fro swing of the pendulum, each motion or action begetting and mutually depending on the other. Hence, in the Scandinavian mythology the tree of life, Igdrasil, is rooted in death and draws its nourishment from decay.

The ancient philosophers regarded the universe as an organism, designating it the greater man, regarding man (*vir*) the lesser world, or the epitome of all created things, calling the greater the *Macrocosm*, and the lesser the microcosm.

Let us look at this analogue for a moment. These bodies of ours we are told are composed of millions of cells—or atoms—of which every member down to the ultimate tissue consists; when one of these small particles becomes worn out and has lost its vitality, it is removed out of the system by an absorbent and in its place is at once deposited a new particle fresh from the heart and lungs, and but recently prepared from food taken into the stomach. Thus are our bodies maintained in working order until old age or accident destroys the erstwhile equilibrium and decay and death ensue. Now the history of one of these atoms in the human body is in epitome the history of a world. Every star in the blue vault had a birth, is passing through its life history, is approaching old age and final dissolution. There may be seen, I believe, stars representing almost every phase of their exceeding prolonged existence, from the nebulous state to the exhausted dark bodies which are supposed to play an important part in the variations of the many variable stars known to exist. I may be allowed to enlarge the analogue and extend the parallel by substituting man homo for man vir and then say, when a man drops off, the race or man homo remains, and when a star is blotted out the stellar universe continues. Nature, always consistent with itself, has ordained in her varied kingdoms certain specific laws and regulations severally adapted to meet the requirements of each department, all working together as a unit. There is a general law, however, which it would seem is common to all celestial and terrestrial phenomena covering even our moral and spiritual natures. We can see its operation in the history of races, nations, civilizations, religions, politics, commerce, meteorology, etc., all of which

seem to be under the spell of that ubiquitous force that imperiously demands submission. Its action may be conceived of as irresistible waves, pulses or undulations or alternating swings of a pendulum, producing on the material plane, crest and trough, flux and reflux or ebb and flow, maximum and minimum cycles, epicycles, series, periods, times and seasons in endless succession. Even those phenomena which are usually considered to be preventible, such as epidemics, homicides, suicides, wars, commercial stringency, financial panics, etc., it may be said, simulate periodicity and make attempt to recur at stated intervals, as though they were due, and must perforce obey the impulse. I now enter upon the main subject.

What Are Nebulæ?

There are to be seen among the stars many small patches of luminous cloudlike appearance, which, on account of their hazy undefined aspect, have been called Nebulæ. Some few of these objects may be seen with the naked eye provided one knows just where to look, and doesn't expect to see too much, and I understand there are thousands to be seen by the aid of telescopes. They are of varied configuration, scarcely two exactly of the same form. These little cloudlets have given rise to much speculation as to their composition, temperature, and purpose. The prevailing opinion seems to be that they consist of material designed to be manufactured into new worlds when the need arises, hence they are often referred to as *star dust*. Such opinion is not free from difficulties, however, for some of them have been resolved into points of light by the aid of high power lenses, thus almost compelling the conclusion that those so reduced are whole stellar systems away out in space far beyond the boundary of this cluster in which our own sun is one of the stars. But that wonderful little instrument, the spectroscope, has decided that the greater number of them are within the limits of our cluster as stars may be seen through them, and some change in form has been detected in many of them, and so it seems pretty safe to say they are as said before, material for new creations, or I would suggest that a moiety of those mysterious bodies are probably the debris of dead worlds in the process of *dissolution*, whilst the other half are the makings of new worlds on the way up—this by the way.

We will now take one of those luminous clouds and try to follow it in the course of preparation under the direction of the supreme chemist and mechanician to take on the function of a solar system. It may help us if we can in imagination transpose all the matter of our solar system into a nebula such as it was I have no doubt, before our world, sun and moon were created, occupying the space, and more perhaps, that is now utilized

by this big circus with which we are identified. I hinted a little ago at two aspects of those nebulous clouds, viz. one descending, the other ascending, and this involves a necessity for a few remarks on a phase of this subject which I was trying to avoid: we can conceive, I may take for granted, a system of worlds in the long run of ages, becoming worn out, as everything else wears out, all its vital energy lost, its heat eliminated and in consequence its motion stayed, its fluids resolved into their elements, its minerals and earths crumbled into dust. So far, we can in a manner follow, but that is only a part of the process. The chemist comes along with his crucible, lens and retorts and he does what it is supposed nature is engaged in doing all the time. He can take hold of this stuff, now to us invisible and by some process, utterly to me unknown——divide and subdivide these fine particles of dust until it becomes absolutely incomprehensible to ordinary beings. He takes the hydrogen or chemical atom and splits it up into a thousand, takes one of the thousand and makes another thousand and so on down, one would say, to nothing. Prof. Kirschman can follow these divisions, if I understand him, until the matter under examination is so small as to be altogether beyond the power of all "attractive or gravitating influences," and (he says) "we may as well call these very minute particles" the elementary physical and psychical entities, or centres of energy, no longer in the form of solid, liquid, or gas, and do not correspond to any of the chemical elements," We may concede that whatever the chemist can do Nature can do better, give her time, and so we allow that the old material which had done duty so far as we can see alternating from eternity and for which we are now waiting to again come in sight, might have remained in that immaterial state for an indefinite time undergoing a process it may be, which it cannot enter into the heart of man to conceive, until it reaches its terminal, rounds its pole, and begins its return journey to material crystallization, having been to all intents and purposes dead and buried (to sense) waiting the returns of its resurrection morn. We must pass over æons of time until we have our material emerging from that hypothetical state, assuming concrete form, being as it were reincarnated in a material body, enveloping its "vital entities" with nebulous cloud, now seen as a nebula among the stars. Having received its commission to take up the appointed role, and being re-endowed with new life to that end, atom joins atom by molecular attraction and forms molecules. These are drawn to each other and form masses, with the formation of masses the erstwhile quiescent force, called gravitation, is aroused into action, and the entire mass is alive with energy. A new force is now being developed. It is known that compressure of matter evolves heat, and that mysterious element, being as I conceive the primal *source* of motion, the agitation in our cloud mass will become

infinitely intensified, and condensation and consequent heat production will proceed at an ever increasing rate.

There is also a law that any loose mass of material will form a centre or nucleus around which to gather (this is beautifully exemplified among masses of humanity) and so this mass of which we are now speaking will consolidate a nucleus, towards which the whole mass will gravitate. Some have supposed that many smaller nuclei would be formed in the outlying portions of the mass that would ultimately become planets and satellites, but my own opinion is that, granting other nuclei were formed, the central and first nucleus would have made such a good start that all minor attempts would be compelled to fall in, for we see even now that our sun, being no doubt much smaller than that mass of which we are now speaking, commands the most distant planet in his dominion to do his bidding. We now conceive that our mass of building material is reduced to much less than half its original dimensions, and has become semifluid by excessive heat, tolerably well rounded off, and moderately compact, ready for a most important advance move which forms a most imposing epoch in its history. We can imagine that mighty ball of matter quivering with energy from centre to circumference, pulsating and palpitating with overflowing life, apparently as eager as a full blood racer for the word of command. When at a given signal the Great Architect and Builder says, Altogether! touches the button and the huge ball rolls over and continues to roll and will not cease to roll until in the long distant future its vitality is exhausted, its heat eliminated, and its set task completed. Hear what Emerson says of this incident: "It was no great affair, a mere push, but the astronomers were right in making much of it, for there is no end to the consequences of the act. That famous aboriginal push propagates itself through all the balls of the system, and through every atom of every ball, through all the races of creatures, and through the history and performances of every individual." The forces are doing their work without ceasing and with increasing energy, our ball is now violently rotating on its axis, a huge globe of liquid fire, at an ultra white heat, or if I may hazard an opinion formed by observation of the behaviour of electric lights, I would say the superheated ball assumed a slight pale blue tinge, indicative of the intensity of the temperature acquired. In due time having attained its maximum of heat and velocity, the time of incubation being accomplished, and the crisis of parturition reached, when it seems impossible to hold itself together any longer, the surface of the whole equatorial zone becomes loosened, and breaks away in enormous sheets and huge fragments containing billions of tons of the molten matter, which acquire such a momentum that it is hurled hundreds of millions of miles off into space. This event of parturition might have been repeated at intervals of longer

or shorter duration as in sentient life, or it might have been continuous without intermission for an indefinite time, or again, the whole family of worlds might have been produced at one birth, by one effective, tremendous cataclysm or convulsion. It matters little which method was followed. We may conclude that the world producing or child bearing age of the sun as in organic life would come to an end, soon after the maximum of heat and rotatory speed was passed, and the cooling process set in.

Before this spectacular scene which I have been trying to depict fades away from your minds I wish to interject an idea which penetrated the grey matter of my brain a few weeks ago and persists in staying there. You have all no doubt heard of new stars, which appear to burst out at intervals, become intensely bright, and remain so for a few days or weeks or it may be sometimes, months, then gradually fade away again into obscurity or into a star of microscopic dimensions. What is the meaning of these strange phenomena? So far as my information goes they are supposed to be the result of collisions between two suns or other large bodies, which, through some mistake it would seem, among the telegraphers of the skies, have got into each other's way and that great flash is the consequence of a terrible head-on, rear-end or broad-side smashing up. Some think they are due to spontaneous combustion. I confess that I was never quite satisfied with that explanation and really believe I have found a more rational as well as much more probable solution. Bearing in mind the unlimited number of nebulæ said to exist in interstellar space, and the highly probable theory that they are new worlds in the making, and admitting the probability of the method or process I have endeavoured to unfold, can it be called unreasonable to suppose that the magnificent outburst of light accompanying such an outspreading of glowing matter all round the circumference of such an immense body as it must have been would be amply sufficient to produce the phenomenae in question, *i. e.*, new star. I certainly and unreservedly think that it would, and the more I think the matter over, the more I am confirmed in that conclusion. The verification of this view would form a striking corroboration of the nebular theory, besides removing a clumsy precedent for all the careless blundering in our transportation systems on earth.

To resume, we left our future sun busily engaged in distributing material for his great family of subordinate worlds out into cold space. Each block we may suppose received an impetus just sufficient to carry it to its appointed place. But long before it had reached its destination, it would have acquired a spherical form, and would be rotating in the same plane, or direction, as the body from which it was thrown. When the new globe now called a planet had reached to almost the limit of the cen-

trifugal impetus a compromise was agreed upon between the two forces; the result of which was that the planet would make a circuit around its parent the sun in a given path and a fixed period of time, a most important epoch in the history of a world. I need not go into detail regarding the different members in our system as to magnitude, distance from the sun or time of rotation or revolution. But I may say that besides those established and recognized bodies called planets, planetoids, satellites and comets, there were millions of millions of tons of loose material scattered in all directions from every point of the then bursting sun and from the flying fragments on the way out to form worlds, which apparently never aggregated into solid bodies but took up a kind of vagrant life. Any amount of such material remained in comparatively close proximity to the sun to mystify future observers as the Zodiacal light, incalculable masses sweep around the sun in swarms, and thousands of tons are annually captured by the earth and doubtless by all the other planets as well as by the sun himself. In fact, space within the area of the solar system must have been filled with that small rubble.

I must now draw this paper to a focus, and confine my remarks to that mass of molten matter which settled down and commenced business at about ninety- wo millions of miles from the sun, which we shall from henceforth call the earth. When this block of molten matter reached its destination, it no doubt was a magnificent globe of ruddy brightness and began at once to revolve around the sun as now and rotate on its axis many times faster than now. In the course of time segregation in the hitherto apparently homogeneous body of this glowing sphere begins. The scattered atoms of the various elements seek their own, when united, seek their affinities, forming the embryo, as it were, of all the diversified constituents of our world as now known. Air, if air it could be called, so attenuated that no kind of living creatures could live by it, and water would remain in a gaseous condition until the temperature of the earth and atmosphere were reduced below 212° F. After many millenniums a thin crust will form over the quivering surface of the still warm globe. The water gas will begin to condense into vapour, commencing most probably in the upper regions of the now settling down atmosphere, being more exposed to the surrounding cold of space. Vaporization of gases keeps pace with the cooling process in the air and on the surface of the earth until the entire surface is covered with a thick impenetrable cloud, which effectually shuts off every ray of light from sun, moon or stars. At this point the most ancient account of the creation I believe extant takes up the parable, and it is certainly most interesting to notice how near that old record comes in many points to the best we now know, A.D. 1909, of the *modus operandi* of creative processes. "Darkness

covered the face of the deep," and if the theory I am dealing with approaches the truth, you see that it must of necessity have been so. In fact it could not have been otherwise. Time passes. The temperature continues falling, and in the upper regions of the atmosphere the cloud vapour condenses into drops of water which soon work their way to the surface of the earth; that operation once commenced will go on with increasing energy, and by the contact of the colder water with the warmer surface of the earth, a war of elements would be inaugurated, which has played such an important part in reducing the earth to a habitable condition. The surface cracks by the contact of the cooler water, and as the water percolates the thin shell, puny explosions and eruptions are produced, which were the sure precursors of those terrible catastrophes we so often hear of in these later days. Precipitation goes on, and as the surface of the earth must still be without deep ocean caves or river channels the entire surface will be covered with water. Meanwhile the water forces its way deeper down through the thickening crust and more violent eruptions occur, which ultimately prepare beds and channels for the universal waters, which again accords with the old Book, "And the spirit of God moved upon the face of the waters" which rushed into the newly formed receptacles made by the volcanic upheavals, "forming seas," and as a matter of course "the dry land appeared." Rain, ages no doubt of rain, would naturally modify the density of the overhanging pall of cloud so that faint streaks of light might have been seen running from east to west over the equatorial zone. (It is supposed that the planet Jupiter is now in a state analogous to that I am now supposing the earth was passing through.) From the constant rain the cloud covering the earth would get thinner and thinner until the light would illumine the entire globe, but the face of the sun cannot as yet be discerned (such was the light the old historian regarded as a light preceding the creation of the sun). Finally the cloud breaks, and the sun appears, next the moon, and then the stars also. Then in the infantile conception of preadolescent man these luminaries were first created. It seems passing strange that in these modern days men should have found it expedient to invent a phosphorescent light to fill the gap, for everything seems to be going forward in such an orderly and natural way. "It's all right with the world." The old writer was not far out when he said "the waters brought forth fish." We may reasonably suppose that had they been furnished in those days with our present day facilities they would have discovered that long before the advent of fish the waters had brought forth thousands of varieties of infusoria, animalculæ and algae to supply the coming species with the means of sustenance even if they had not got down to amœba and protoplasm. Meanwhile the land brings forth the primitive forms of flora, "the tiny

lichen inserts its delicate rootlets in the thin crust of soil." Having given foothold to the flora and fauna in ever so humble or crude manner, evolution will see to it that all things follow in their own proper order. If it be asked whence Life? I ask whence God? Life is spiritual, science will never handle it. We cannot say, here lo! or lo! there. Wherever God is there is life, a universal principle, and wherever conditions can be made to serve a given end, corresponding forms are evolved, or formed, to meet nature's requirements.

THE SETTLEMENT OF NORTHERN ONTARIO.

BY THOMAS SOUTHWORTH.

(*Read 17th April*, 1909).

Ontario is very rich in natural resources of various kinds; resources that are exhaustible, such as minerals; resources that are exhaustible but that may be renewed, such as water and forest; and resources that are inexhaustible in the shape of agricultural soil.

So far as the first resource is concerned, all we can do is to prevent waste. No effort on our part can increase our resource in minerals or perpetuate it if it is used. Water, on the other hand, so far as its purpose for power and transportation is concerned, is dependent for its permanence upon the way we treat the soil, whether we denude it entirely of its timber growth, or whether we protect the head waters of the streams by keeping the land, which in most cases in these localities is unsuited for agricultural production, in forest.

Just what the proper proportion of wooded to cleared land should be to properly protect our immense wealth in water powers, is a question not definitely settled, but it is pretty generally conceded that at least a fifth of the area of a country such as ours should be kept tree covered. Fortunately for us the physical conditions of this Province are such that there is not likely to be any difficulty in maintaining more than that proportion of our area in forest. Even if we were to eliminate the wood lot that every farmer should maintain on his farm, there would still be the necessary proportion of forest land if the area that is quite unfitted for agriculture were maintained in forest.

For the better understanding of the position, Ontario may be divided into four divisions. First there is the strip of country along the St. Lawrence, Lakes Ontario, Erie and Huron and Georgian Bay, where population is most dense, and where agriculture has been most developed. North of this is what may be termed the permanent, or what should be the permanent forest area of the Province, taking in the Laurentian Range, and including the height of land dividing the waters flowing into the St. Lawrence system from those flowing into Hudson's Bay. North of that again, there is an agricultural area stretching from the Quebec

boundary west to Manitoba, of varying width, but containing in the aggregate an extensive area of first class agricultural soil frequently referred to as the Clay Belt of the north. The fourth division lies beyond the strip of agricultural land and forms an extensive area of swampy or muskeg lands, too low to be easily drained, and at present too wet to produce even timber of any size.

Now, agriculture is the source of success and material welfare of any nation. The greater the development of agriculture, the greater the nation. When agriculture decays or is neglected, the nation is in danger of decadence.

In the Canadian Federation or Dominion of Canada, Ontario is still the premier province. In population, in wealth and in influence this province easily outranks any other of the federated provinces. This pre-eminence is largely on account of our agricultural production. True, our manufactures are increasing, and we are producing minerals to some considerable extent in spots, but agriculture is easily first in wealth production. Though only a small part of the area of the Province is under cultivation, our agricultural production is much larger than that of any other province. We are a dairying and stock raising province, yet even in cereal crops our product is greater than that of Manitoba and the northwest provinces.

It must be borne in mind that this production is achieved on about twenty-three million acres out of the one hundred and twenty-six million acres in the Province. I do not mean that twenty-three million acres are actually cultivated, but merely that about that amount of land is sufficiently settled to be under some form of municipal government.

I have stated that Ontario is now the leader in population and wealth in the Dominion, but it must not be forgotten that the western provinces are rapidly filling up, and if we are to maintain our lead, we will need to move faster than we are at present doing in increasing the area of cultivated land.

True, we are developing a mining industry in the north to some extent, but the ephemeral nature of the mining industry, especially in the matter of the precious metals as is the case with us, is such that a mining population cannot be relied upon for the solid upbuilding of a country.

Our lumber industry is and has been very extensive, and though it, like agriculture, may be made a permanent source of wealth and population, the present outlook in this direction is not promising.

I maintain, therefore, that our future relative greatness and position in the Dominion will depend on the extension of agriculture. This extension can take two forms: more intensive cultivation and better methods over the area now under crop; or extension of that area to include the large agricultural area still unsettled. Mr. C. C. James, the Deputy Minister of Agriculture for Ontario, has pointed out that an increase of ten per cent. in the average crop per acre would increase our annual wealth by over twenty million dollars ($20,000,000), and there is reason to hope that the educational propaganda of the Department of Agriculture will in a short time produce this result. This may be done, however, without any increase in population, as the adaptation of new farming machinery and labour-saving devices from time to time enables a considerable increase in output without any increase in human labour.

Fortunately for us, we have a very large area of agricultural land still unsettled, and to this we must look for an extension of our population and an increase in our national wealth.

Some years ago, the Legislature passed an Act to Establish Forest Reserves for the purpose of growing continuous crops of timber, the property of the Crown, the idea being the adoption of a policy of separating for all time the two classes of land, agricultural land and timber land. It happens that the land in Ontario that is quite unsuited for agriculture is the land that lies at the head waters of our rivers, so that in putting in forest reserves for permanent timber crops the land which is only calculated for that kind of crop, we at the same time, while securing a perpetuation of our present provincial income in that particular, protect our water powers without encroaching on the land that ought properly to be devoted to agricultural purposes.

A start has been made in the direction of these permanent reserves, and some ten million acres of land, containing a good deal of valuable timber, have been placed in reserves. This is probably only a quarter or a fifth of the area that should be placed in reserves.

North of the land that should properly be reserved for forests, lies our largest available resource in the way of agricultural land. This will approximate, all told, about twenty million acres, sixteen million acres of which lie in one block termed, as stated, the Clay Belt.

The problem, therefore, of an increase in population, and the maintenance of our position as the premier province of Canada, largely centres in the satisfactory settling up of this large tract of land. A start has been made in this direction. A very large number of townships have been sur-

veyed and subdivided in this area, probably over one hundred; a railway has been built by the Province running into this Clay Belt through the eastern portion of it for a distance of about one hundred miles. Only seven townships out of the hundred have been declared open for settlement, although the railway has been running into it now for two years. There have also been established two Crown Lands Agencies for the sale of land, one at Matheson, and one at Cochrane, the junction point between the Provincial Government Railway and the Grand Trunk Pacific. The Cochrane Agency has four townships for settlement; the Matheson Agency has three. These two agencies are about fifty miles apart. The intervening townships, although lying along the railway, are not yet open for settlement. No roads have been built as yet in the district, or no attempt to assist settlement made further than to provide prospective settlers with the opportunity to apply for land locally.

The settlement of Northern Ontario is not an easy matter. In the first place the growing season is short owing to the climate. The land is all tree covered, and has to be cleared at a very great expenditure of labour and time. In attracting settlers to this country we have to compete against the prairie lands of the western provinces where the land is said to be ready for the plough, and towards the settlement of which the whole energy of the Dominion Department of Immigration is directed.

A settler going to the northwest, however, needs to have sufficient means to enable him to live for the few months necessary to secure a crop from his land. The result is that most settlers with any means go to the northwest, leaving only those who are too poor to undertake the long expensive trip and wait for returns, to settle up the lands in Northern Ontario. These settlers in Ontario are usually able to live from the proceeds of the timber on the land that they purchase from the Crown, at least during the time that timber is being harvested.

The ordinary settler going there without means is obliged to sell the merchantable timber from all over his lot of one hundred and sixty acres to provide himself with the means of living, or else he is obliged to go off his land and work for someone else for wages. Owing to the building of railways and other public works, this labour has so far been largely available, but while he is lumbering or while he is working on the railway or elsewhere for wages, he is not improving his land, hence agricultural development in Northern Ontario has been exceedingly slow.

In 1901 the writer organized a land seekers' excursion to the district of Temiskaming, a million acre tract of land south of the Clay Belt, but

with a soil very similar to the latter. This land was also heavily covered with spruce, jack pine and other timbers, for which the settlers found a ready market. The land in the district was very rapidly sold in 160 acre lots, but although the great development took place there in 1901 and 1902, and although exceptional prices for farmer's produce were received owing to lumbering, mining and other work in the vicinity requiring large supplies of coarse grains and roots, the agricultural progress has been very disappointing. Only a few settlers are even yet actually depending on farming for a living. Large areas that are held by settlers and so called settlers have only a small clearing and a very poor shack upon them, in spite of the fact that the soil is very productive and prices are high.

When a settler in that district buys a lot from the Crown, he does not get the title or patent to the lot until he has cleared and put under cultivation sixteen acres and has lived continuously on the land for four years. Until this patent is secured he cannot mortgage the land, that is to say, he cannot borrow money for the purpose of developing his farm. If he is so unfortunate as not to be located upon a colonization road, he is unable to build a road himself, owing to the great cost, hence he feels he would be wasting his time to stay upon the lot and merely exist. He naturally goes out to work, and only does enough work upon his land to prevent its being resumed by the Crown.

Our whole system of land settlement, or rather, I should say, lack of system, for system we have not, is well calculated to keep that country in an unsettled condition and merely affords an opportunity to men to go in and make what they can out of the sale of the timber on the land.

In the first place, it costs about $1,000 per mile to build a fairly good wagon road for the use of the settlers, and without this road they cannot take their produce to market, nor get supplies in to support their families except upon their backs. In most of the townships the land is laid out in blocks half a mile square, so that only four settlers are accommodated by a mile of road, which would mean $250 to each settler to build a road. As these settlers are for the most part poor, the roads are not built.

This, added to the fact that they cannot borrow money, having no security to offer, makes settlement there an exceedingly tedious and disheartening operation. If a private individual owned this land and had sufficient capital, or could acquire it, he would, to make the most of it, undoubtedly provide some system of loans to settlers and adopt some plan of co-operation by which all the settlers in a township could be provided with the necessary wagon roads. Why should the Province not do so?

The Dominion of New Zealand and some of the Australian provinces have for many years been in the habit of lending money to settlers, taking means to see that the money loaned was applied to improving and developing the settlers' holdings. In this way, the security held by the Government is increased, for the land is improved in value to the extent of the loan, plus the settlers' labour. The Government borrows money and loans it again at one per cent. advance. This one per cent. has paid all the cost of administration, and made up for all the losses. Surely the Province of Ontario could help our new settlers (and the settlers in our north country are largely Ontario people) to this extent.

It has been urged that political pull would interfere with the successful working out of such a plan, but it seems to me this could be safely avoided. In New Zealand every application for land is made to a Local Land Board as to a bank, and the applicant must establish his worthiness before the loan is made. On the recommendation of this Land Board the money is loaned by the Government officer entrusted with the funds, and on their recommendation only.

If the settler could obtain a loan at reasonable interest, and the Government would of course hold the land as security, he would be enabled to proceed with the clearing and development of his farm instead of having to go out to work and keep his family in the nearest village, as at present.

The question of roads, also, it seems to me, might be handled in a much more systematic way. At present the Government of the Province expends a large amount of money each year in building a certain extent of wagon roads in the way of colonization roads. In some cases these roads are planned on a definite scheme laid down by the Department of Public Works, and sometimes built without any particular scheme, but according to the amount of influence possessed by the settlers who petition for the road.

In the newer districts, however, usually not more than six or eight miles of road are built in any one township. This road is built at the expense of the Province, and without any charge upon the settlers living along the road. That is to say, the settlers who are fortunate enough to procure land along concession three, we will say, have a road built for them entirely at the Government expense, while the settlers on other concessions either do without a road or build it at their own expense, say $250 per man, while paying as much for their land as the more fortunate settlers who live on concession three.

It appears to me that the Government might very well undertake to build all the roads petitioned for by a majority of the settlers living on a concession, making the cost of this road a charge against the land, to be collected over a term of years through some special machinery designed for the purpose, or by the municipal organization when it is formed. This would be merely an application of the local improvement plan in force in nearly all our cities and towns, except that instead of the municipality furnishing the credit as in the case of the urban municipalities, the Government, in the absence of any municipal organization, would have to furnish the credit in our newer districts. $250 is an enormous amount of capital to put in a road in the case of the ordinary settler in Northern Ontario at the beginning of his undertaking to establish a home in the forest. The building of this road, however, will so enhance the value of his land that he could very well afford to pay that amount with interest back to the state in the form of road tax after he has got his farm in producing condition.

The soil in Northern Ontario is, I am convinced, as rich and productive as can be found anywhere. The season, though short, is sufficiently long and the growth sufficiently rapid to permit the growing of agricultural crops successfully, as has been demonstrated in Temiskaming and even much farther north. All that is required for the rapid settlement and development of our northern agricultural region is the adoption of a systematic plan by which settlers can be given some assistance in getting established, and this can, in my opinion as outlined above, be done without impairing the revenues of the State. There seems to be a tendency to regard the chief duty of the Government to be that of securing present revenue, thus avoiding direct taxation upon the people as a whole. But while it is eminently right that the people as represented by the Government should receive the proper share of revenue from the exploitation of our natural resources, the future welfare and development of the Province is of far greater importance.

THE HABITS AND LARVAL STATE OF *PLETHODON CINEREUS ERYTHRONOTUS.*

By W. H. Piersol, B.A., M.B.

Although *Plethodon cinereus* is considered by Cope ('89) "the most abundant salamander in the northern and central United States" its habits and development have received but little attention. Cope ('89) gives a brief outline and Wilder ('94) a scant mention, Montgomery ('01) adds a few points and describes the larvæ of one bunch of eggs. Reed ('08) discusses the coloration of adults. Kingsbury ('95) touches on the questions of the transference of sperm and the season of egg-laying but without coming to any definite conclusions. Sherwood ('95) gives a date on which eggs were found. As regards *Plethodon oregonensis* the behavior in captivity of a female found with her eggs is described by van Denbrugh ('98), and Hubbard ('03) deals with some protective devices. There are several other papers in which Plethodon is mentioned but without reference to habits or development. The observations recorded below have been made partly in the field, partly in the laboratory, and on specimens from several localities, all however within a radius of fifteen miles from Toronto. Unless recorded as single occurrences, all observations have been verified in at least one subsequent season. Cope ('89) divides *P. cinereus* into three sub-species of which *P. cin. cinereus* and *P. cin. erythronotus* only are common. For the sake of ensuring uniformity the latter variety alone forms the subject of this paper. Many larvæ of *P. cin. cin.* have also been found and comparisons made with similar stages of *P. cin. eryth.* show that in the larva as in the adult the sole distinction between the two varieties is the coloration. The difference in geographical distribution which Cope mentions is not invariable, one bit of woodland may yield the two varieties in about equal numbers, another quite similar but a few miles away may contain *P. cin. eryth.* in abundance and but few *P. cin. cin.* No locality yielding either variety alone, or a majority of *P. cin. cin.* has been met with.

The typical coloration of the two sub-species is closely adhered to, the intermediates noted by Reed ('08) are very rare and even then approach closely the types; and only one specimen with much more than the normal amount of red was found. About 250 adults have been under examination, a number not so great as that used by Reed but sufficient to show that in

this region there is less variation in colour than in the one where his studies were made.

Plethodon cinereus may be found in almost any wood in which the underbrush has not been entirely cleared away. They seek shelter under logs, fallen branches, flakes of bark separating from old stumps, or even masses of decaying leaves; the cracks of rotting logs and stumps are also favorite places. In the latter situation the variety *erythronotus* receives some protection from the red in its coloration, the shade of red is often that of the decaying wood and the dark edging is a fair reproduction of the dark and narrow cracks that run through the log. Occasional specimens may be found in the latter part of April; during the next three weeks they become abundant and by the middle of May can be found as plentifully as at any time in the year. Just where they pass the winter has not been determined though search has been made both early in the spring and late in the autumn; digging quite through stumps and logs embedded in the soil will not expose them, though it will probably result in finding the wood-frog, *Rana sylvatica*. A few trifling things have suggested that the animals follow down the cracks in the roots of old stumps to a considerable depth, but this has not been verified. Farther south Montgomery ('01) finds them in the same situations both winter and summer.

Plethodon is strictly nocturnal, so far at least as regards life above ground; however, a specimen that is suddenly uncovered is by no means dazzled by daylight; it may remain motionless for a minute or two or may at once crawl beneath the nearest shelter. Nor does it stop when under cover but keeping out of sight crawls rapidly to a considerable distance, so that if not captured as soon as exposed it runs a very good chance of escaping entirely. This sensitiveness to light has rendered disappointing the results from keeping specimens in a terrarium, an amount of light sufficient to reveal them at all either arrests all movement or sends them under shelter.

An examination of the stomach contents shows the food to consist of a variety of small insects; in one case the remains of a small spider were found.

In handling living specimens it will frequently happen that the end of the tail will apply itself closely to a finger in a semi-circular loop, and hold thus for a few seconds. This power may perhaps be regarded as the first step in the development of a prehensile tail such as is described for Autodax (Ritter & Miller, '99).

Two habits of Plethodon deserve notice as being of rare occurrence among Urodeles. When excited it occasionally aids its progress by leaping. In such cases as have been observed under conditions that admitted measuring the length of the leap it has been found about equal to the length of the animal's body. If the animal is running on a rather even surface it lands on its feet and continues the run having gained by its leap; but it will just as readily leap into difficulties. Held in the open hand it will frequently leap off, no matter what may be the height of the hand above the ground. In jumping the back is slightly arched and the front limbs with most of the trunk are raised in the air to about the height of one centimetre; then with a snap the tail is slapped against the surface over which the animal is moving and the body sharply straightens and shoots forward. The whole movement is so rapid that it cannot be distinguished with certainty whether the limbs aid in the leap. Two things suggest that they do; it is difficult to imagine a force to raise the anterior part of the body to the height it attains if it does not chiefly lie in a spring given by the anterior limbs. The posterior limbs are even stouter and are in a good position to aid in the forward propulsion. The young as well as adults possess this power of leaping, indeed the only specimen observed to give a succession of leaps, three in fact, was one of 24 mm. The explanation of the greater development of the posterior limbs in the later larval stages, noted by Montgomery ('01), may lie in this habit. In this connection Cope ('89), says: "It frequently climbs to the summit of low vegetation, from which it springs by a sudden straightening or curvature of the body, as the case may be, in the manner of a caterpillar." The curvature and straightening in leaping are evident; the climbing of low vegetation to leap from it has not come under observation.

The second noteworthy habit is also connected with escaping enemies. Plethodon will sometimes break off a portion of its tail. Two things suggested the existence of this habit before it was actually observed. In searching for Plethodons in decaying logs not infrequently as the covering is lifted the animal will be found crawling stealthily away from the bit of tail that is making itself very conspicuous by its violent movements. This will occur at times when so little force has been used in picking apart the log that it is difficult to conceive how the piece could have been broken or pinched off. Again about 10% of all specimens found show the end of the tail in the process of regeneration, raising the suspicion that it is a mutilation out of the ordinary. On one occasion when a young Plethodon had been repeatedly touched by a small rod it suddenly gave a jump breaking off at the same time the terminal third of its tail. Two

adults while being held lightly by the tail cast off a portion of it, the separation occurring in the part grasped and leaving in the one case a stump 1 cm. and in the other 1.75 cm. long, measuring from anus to end of stump. In no case observed has the length of tail retained been less than .5 cm.; it was usually more. There does not seem to be any one place where separation greatly tends to occur. Incomplete separation has also been noted, the vertebrae and muscles separating but the skin failing to break; this causes a slight grooving of the tail as though an invisible thread were tied around, compressing it. Longitudinal sectioning was used to examine both proximal and distal pieces in those cases that occurred under observation, and the relation of parts in the wound was found to be as follows, (Figure 1.) Separation of the vertebral column occurs between vertebrae; this is the condition also in *P. oregonensis* (Hubbard, '03). In the muscle the myomeres are not broken but separation occurs in the myocomma opposite the middle of the last vertebra retained. The skin however does not break here but at the myocomma opposite the middle of the first vertebrae of the piece cast off. Two things are accomplished by this; first the wound that now terminates the animal's tail is protected by the extra length of skin which collapses laterally upon it and almost covers it in. Second, on the piece cast off considerable raw surface is left exposed, the irritation from which is doubtless largely responsible for the rapid contortions that occur. This piece must play an important part in the protective device for by its violent movements it would draw the attention and invite the first attack of an enemy.

A similar habit has been noted in *P. oregonensis* by Hubbard ('03) but there are distinct points of difference. Briefly in *P. oregonensis* on moderate stimulation the glands on the dorsum of the tail swell greatly and pour out an abundant secretion. Only the most powerful stimulation—the act of being swallowed by a snake, or being plunged into a fixing fluid without previously being anæsthetized—would rouse the animal to the point of sacrificing its tail. Separation always occurs at a constriction just behind the anus. No mention is made of the behaviour of the piece separated and, the subject of the paper being correlated protective devices, it is perhaps fair to assume that it presents no striking peculiarity. In *P. cin. eryth.* the tail shows neither constriction nor swelling nor does the great development of dorsal glands occur, the thickness of the dorsal skin being one-twelfth to one-eighth of the diameter of the tail, while it constitutes one-fourth of the swollen tail of *P. oregonensis.*

Owing to the extreme aversion to light already mentioned it has been impossible to ascertain in a terrarium the manner of fertilization of the

eggs. That fertilization is internal, and that it precedes egg-laying by a considerable time may be inferred from the following. The female is provided with spermathecæ which are already filled with spermatozoa at a time when the eggs are yet in the ovaries and have not attained a greater diameter than two mm. Quite likely the spermathecæ are filled long before this because at this time no spermatozoa are to be found in the genital tract of the male. The testes are filled with spermatocytes which as Mongomery ('03) describes undergo their maturation during the summer; spermatozoa may be found after the middle of August. Further observations are necessary to determine whether transference occurs in autumn or in spring.

Although there is a total lack of secondary sexual characters it is usually possible to distinguish between the sexes owing to the thinness and translucency of the muscle and skin. Because of the dark colour of the testis and the light colour of the eggs the posterior part of the abdomen when viewed from beneath is dark or light according as the specimen is male or female. This distinction is most evident in the spring, the eggs being largest at that time but in most cases it can be made at any season. In addition, the cloacal glands of the male cause a whiteness and a swelling at the sides of the body just behind the posterior limbs.

There is considerable latitude for a Urodele in the time at which egg-laying occurs. The earliest date on which eggs have been found was June 16th—3 clusters, the eggs in early stages of segmentation; the latest is July 3rd—1 cluster, in the same condition. The difference is not due entirely to different seasons being early or late, nor to one bit of woodland being better sheltered and warmer than another, for clusters of eggs with the females on guard and other females with the season's eggs yet in the ovaries have been found in the same log on the same day. The date, Oct. 25th, given by Sherwood ('95) for the finding of eggs of Plethodon is not accompanied by any description of them; and its exceptional lateness leaves the meaning of his observation doubtful.

The eggs of the one individual seem to be deposited all at the one time. No female was found guarding a cluster of eggs having also any in the oviduct or even in the ovary that were nearly full size. It is however not at all uncommon to find an egg in one ovary about half-size; this should be associated with the small egg of some bunches described below and considered as one that should have been laid this season but which, having failed to develop its proper amount of yolk, is retained in the ovary.

As a situation for the eggs marked preference is shown for logs almost entirely embedded in the humus, logs that have decayed to a point where the substance is friable with large cracks running lengthwise. In one

of these cracks the eggs are hung from the roof like a little bunch of grapes (Figures 2 and 3). Rarely a similar cavity within a decaying stump is selected. All the localities in which Plethodon has been found contain conifers and almost without exception it is in coniferous wood that the eggs have been found; though the adults may be found plentifully in wood of all kinds. Usually the eggs are placed from three to five inches beneath the surface of the log, at which depth its substance is constantly moist, and it can well be imagined that the air is saturated with water vapour. They are always accompanied by the female and if in exposing them she has not been alarmed she will be found holding the dorsal surface of her head and neck against the under side of the bunch. That it is the female that remains on guard was determined by the dissection of over twenty specimens. In only one case was a male found by eggs and then in company with a female; the eggs were several days advanced in development and the presence of the male was perhaps merely an accident. Cope ('89) and Mongomery ('01) speak of finding the animals and their eggs under stones but if the above mentioned shelters are available they are always preferred. Wilder ('94) notes that the adults are seldom to be found under stones. Sherwood ('95) gives the habitat as beneath logs and stones, while the eggs are to be found in damp moss and beneath the bark of decaying stumps.

Among Urodeles that do not lay their eggs in water contact between the body of the female and the eggs seems to occur in all cases; Amphiuma (Hay '88) and Autodax (Ritter and Miller '99, and Ritter '03) coil round them, Desmognathus (Wilder '99) inserts herself among the eggs wearing them like a necklace or belt. *Plethodon oregonensis* (van Denbrugh '98) is described as holding the bunch in a loop of her tail and moving them from place to place. But as this was after removal from their natural surroundings it is quite possible that the eggs had been torn from their original support and that part of the mother's uneasiness arose from their unattached condition. The Cæcilians (Gadow '01) also when not viviparous coil round their eggs.

The number of eggs in a cluster varies from three to twelve. The number of ovarian eggs in advanced condition, in specimens taken just before the egg-laying season is also within these limits and the length of the incubation precludes a second brood in the one year. Consequently the preservation of the species must depend upon the larval stages being so perfectly adjusted to surrounding conditions that the mortality is very small, rather than—as is the case with most Urodeles—upon the production of large numbers of young. The slender and almost cylin-

drical form of body (the proportion of length to greatest breadth being fourteen to one) in an animal so small, along with the necessity for producing eggs containing a large amount of yolk are doubtless factors determining the small number of eggs; another will be mentioned later.

The necessity for the large amount of yolk in the egg arises from the purely terrestrial development of the larva. Aquatic larvæ have at command the minute and abundant fresh-water plankton as food supply and are thus at an early age rendered independent of the nourishment provided in the yolk. The insect life that constitutes the early food of the terrestrial Plethodon is of larger size than much of the plankton and much less abundant. Consequently the animal on leaving the egg must be able to wait for food through comparatively long intervals and also to capture food of larger size than an aquatic larva need do. Both of these things demand an advanced development that can only occur when a considerable quantity of yolk is provided.

Each egg is surrounded by a series of mucous spheres as is customary in Urodeles. In their natural condition the number of these is rather difficult to determine but after soaking a few minutes in water they swell somewhat and the following is plainly seen:—an innermost sphere very close to the surface of the egg; a second enclosing this but separated from it by a greater interval than that between the innermost sphere and the egg; occasionally this sphere is represented by two, one of them fitted very closely around the other. The outermost sphere—usually the third—fuses with the outermost spheres of neighboring eggs at all points of contact. On its surface are threads and bands of a milky white mucus which seems tougher than the rest, which is transparent; these are especially numerous between eggs and at the upper part of the bunch where several uniting form the stalk by which the cluster is suspended. This mode of attachment is probably derived from one originally like that of Desmognathus (Wilder '99) in which each egg of the cluster is independent of all the rest and has its own cord joining it to the common stalk. The tension of the envelopes, especially the innermost, is needed to preserve the spherical shape of the egg. These envelopes are very tough; a weak hypochlorite solution will soften them so that they can be removed but when their support is gone the egg, even in water, flattens until the vertical diameter is little more than half the transverse. In the younger stages it is therefore necessary to fix and harden the egg first and remove the membranes later, they should be removed as soon as possible for if left around the egg the latter will in time disintegrate. The method devised by Morgan ('91) has proved the most satisfactory.

As development proceeds the amount of fluid between the egg and

the innermost sphere increases markedly, thus relieving the growing embryo from pressure.

The eggs vary from 3.5 to 4.5 mm. in diameter. In many of those bunches which contain several eggs there is one egg considerably smaller than the others; with this exception there is great uniformity in the size of the eggs of the one cluster. The considerable variation noted above exists between the eggs of different clusters.

The colour of the egg is a very pale yellow, a tint due to the yolk for no pigment is present. The upper part of the egg being the more free from yolk is almost white. Variation exists in the tint of the eggs of different clusters, the range being between very pale cream and light orange-yellow.

The usual rotation of amphibian embryos in their earlier stages occurs also in Plethodon but is modified by the large amount of yolk present. In the usual type of amphibian embryo, such as Amblystoma or Rana, the amount of yolk is not so great as to render it impossible for the embryo to turn over when the course along which the ciliary movement urges it so demands. Until the Plethodon embryo has reached a length of 6 mm. it lies along a meridian of the yolk mass and a true forward movement would require the yolk at times to be uppermost. Whether because the ciliary movement lacks force to drive it into this position or for some other reason less obvious the rotation that occurs is around the vertical axis. There is no uniformity of movement even in eggs of the same bunch; an occasional one will be motionless and the others about evenly divided between motion to right and motion to left. A little later when the embryo twists itself into the horizontal plane the appearance in rotation is that of the ordinary amphibian embryo but the same lack of uniformity of direction obtains, some few embryos will not be moving at all, of the rest the head will be preceding in some cases but the tail in quite as many others. This latter direction was not expected and caused an examination of Amblystoma eggs to be made subsequently to determine if anything comparable was to be found there. Eycleshymer ('95) notes an early irregularity of direction but this is not the impression derived from a brief examination of larvæ in later stages; nor is it to be expected from the account of the ciliation of Rana and Triton larvæ given by Assheton ('96). The stage of developement of Amblystoma equivalent to the one of Plethodon in which the backward movement is so marked is that in which the gills are beginning to appear and the larva is curved laterally in a semicircle to accommodate itself to its spherical envelope. At this stage nearly all embryos examined will be

found moving slowly forward very nearly in the horizontal plane of the body; some few will be motionless and about 1% will be moving backward. It is not difficult to mark these latter by thrusting small splinters of wood through the jelly until their points almost touch the sphere surrounding the larva; a few hours later these individuals will be found moving forward and another set moving backward. Reversal of direction has also been noted in some Plethodon larvæ. Evidently the condition in Plethodon is nothing peculiar to the genus but an exaggeration of one found elsewhere among Urodeles. How widely spread it may be and whether it means a reversing of the usual movements of the cilia are points left for future determination.

The rate of rotation varies greatly, extremes of one minute and three and one half minutes having been noted under similar conditions.

The service of the rotation to the embryo probably is that it prevents adhesion between the egg and the envelopes. Smith ('06) found this occurring in eggs of Cryptobranchus lying in dishes in the laboratory; interference with development resulted. He makes no mention of rotation in the eggs but suggests that gentle rocking due to the current of the stream in which the eggs are laid prevents adhesion under natural conditions. Apparently in eggs laid in waters that have no current—as Amblystoma or Rana—or in other equally quiet situation—as Plethodon—the rotation suffices to prevent adhesions until the embryo beginning muscular movements is past all danger of their occurrence. Besides rotation other movements in embryos of 6 to 7 mm. are performed at intervals and consist of elevating the head from the yolk and waving it from side to side. As development proceeds these movements pass into occasional wrigglings of the tightly coiled larva whereby the whole position within the envelope often becomes altered.

Development and growth are very rapid for a few days, an embryo of 5 mm. will increase in length to 9 mm. in six days; but at this point the processes become much slower and to increase from 9 mm. to 11 mm. requires fourteen days. This change in the rate of growth is shown very plainly in sections by a sudden diminution in the number of mitotic figures which from being very numerous in the smaller embryos become rare after the length of 9 mm. is passed. In its later stages development is retarded in the central eggs of a cluster where the embryos are smaller and show but little reduction of the gills while the outer ones are larger and have the gills almost entirely absorbed (compare Figures 13 and 14). Measurements of a typical case gave central embryos 17.5 mm. with gills 1.75 mm. long and outer embryos 20 mm. with gills reduced to

.25 mm. A similar condition is found in Amblystoma, Rana and other amphibia where the eggs are laid in clusters; the cause being the difficulty with which respiration is carried on in the central eggs.

Escape from the mucous envelope occurs when the larva has reached the length of 20 to 25 mm.; this is about the first week of September. The outer larvæ of a cluster escape first but remain with the mother beneath their less developed brethren. Respiration is now more perfect in these; in a few days their gills have dissappeared and they also escape. However the interval does not suffice to bring them so far on in development as were the outer ones when they escaped; they have absorbed less yolk and are shorter. They also seem unfit to come in competition with their more favored brethren of the outside of the bunch of eggs, their movements being comparatively feeble and ineffective; many of them probably die. Thus is supplied another factor tending toward the production of small numbers of large eggs; for those young will be best fitted for life that come from broods where all the nourishment available as yolk is divided among but few eggs, so few that none are crowded into the centre of the cluster.

The family does not scatter at once, an unusual thing among Urodeles that have attained their adult form, but accompanied by the mother, perhaps led by her, the brood leaves the interior of the log to live beneath stones, fragments of wood or bark, lying on the surface of the ground, or even among layers of mouldering leaves. If not disturbed when uncovered the young will be found in contact with the body of the mother, probably to obtain moisture; for the localities in which they now are contain little moisture at this season of the year. The families do not hold together for long. In the latter part of September a few solitary young will be found and early in October all the broods seem to have broken up. The rate of growth in Plethodon must vary enormously in different individuals, for at this season it is easy to collect a series beginning with young accompanying the mother and ending with full grown specimens, the increase in size being so gradual that it is impossible to draw with certainty a line between this year's and last year's broods. Apparently the ability to withstand the winter is independent of size for early in May an occasional specimen will be found that is little larger than the young at the time they escape from the egg—that is less than 30 mm. in length.

The following description of the external appearance during development is based upon the examination of over 170 embryos that had been fixed in Zenker's fluid and preserved in 80% alcohol, the members of each

bunch being kept together and separate from other bunches. In the series twenty different stages of development are represented, though only the most important of them will be described. As the eggs vary somewhat in size so do the individuals of the same stage of development; the descriptions given are those of average specimens, extremes in any direction (very few in number) being disregarded.

The embryo may be considered as well defined upon the yolk when the medullary folds are complete and approximated through a little more than the posterior half of their extent. (Figure 4). Together they give this part of the embryo a width of .75 mm. except at the posterior end where they separate slightly before becoming continuous giving here a width of 1 mm. In their anterior part the folds are widely separated giving to that part of the head an extreme breadth of 1.5 mm. In front of this part an almost transverse piece connects them while behind it, they converge, meeting at a point a little anterior to the middle of the body. In living specimens placed in a strong light a delicate scalloping of the inner margins of the folds in the cranial region indicates clearly the neuromeres, but no method yet used has succeeded in preserving them through fixation. In a corresponding stage in the eggs of some Amphibia the areas of brain substance that will form the optic vesicles are indicated by depressions, sometimes pigmented (Eycleshymer '93), but in Plethodon no trace of these can be found. The length of the figure defined by the medullary folds is three millimetres.

Larva 5 mm. Figure 5.

The form of the body is still determined by the yolk and the central nervous system. The medullary folds are in apposition throughout. The head is raised off the yolk as far back as the midbrain; eyes and ears are indicated externally. Behind the head the mesoblast makes a border on each side of the spinal cord extending but a short distance laterally over the yolk. The anterior three-fifths of it is divided into ten somites opposite the third and fourth of which it is thickened forming the beginning of the anterior limb. The posterior two-fifths of the mesoblast is not yet divided into somites. The medullary folds flatten and a little in front of the well marked blastopore disappear.

Larva 5.5 mm. Figure 6.

The pharyngeal region is now distinct and shows four gill arches; sections, however, show that the gill slits are not yet perforate. Posteriorly a crescent shaped furrow, the horns pointing forward, defines the termination of the body and marks its tendency to rise off the yolk.

Though thus hidden from view by the beginning of the tail, sections show the blastopore opening into the bottom of this furrow. At this time the increase of fluid around the egg begins. The whole body is assuming a cylindrical form and standing out from the yolk which is slightly flattened near it, and markedly flattened in the region against which lies that part of the body from the anterior limbs forward.

Larva 6 mm. Figure 7.

During the growth from 5.5 mm. a twisting of the anterior part of the body through 90 degrees has occurred so that one side of the head is now turned toward the yolk; of eleven specimens this was the right side in nine, the left side in two. That portion of the body attached to the yolk, *i.e.*, all posterior to the pharyngeal region, shares in the twisting and becomes curved laterally upon the yolk in such a fashion that the anterior three-fourths of the dorsal surface is brought into the one plane. Opposite and external to the last three somites now distinguishable is, on each side of the body, a low mound of thickened tissue—the beginnings of the posterior limbs. The terminal millimetre of the tail is quite cylindrical and free from the yolk. The first traces of pigmentation now appear on the dorsal surface of the anterior part of the body.

Larva 9 mm. Figure 8.

The anterior part of the body has more than doubled in thickness and has grown so far off the yolk that the anterior limbs are now free from contact with it. This gradual freeing of the body from its attachment to the yolk is brought about by growth of the central part of the body crowding off the extremities, accompanied by but little pinching off of the connection between body and yolk; for the length of body attached to the yolk has remained, and will for some time yet remain, constant at 3.5 to 4 mm. As the body is thus projected forward those parts of it that were spread out laterally on the yolk move ventrally and unite in the middle line. This is well shown in the anterior limbs which from projecting dorsally as at first are compelled by this movement at last to point outwardly. They are now .35 mm. long. Similar growth backward has brought the posterior limbs to the verge of the attachment of body and yolk posteriorly. These limbs are yet represented by rounded thickenings only. All traces of the gill arches have disappeared from the surface while the external gills have appeared as three points .25 mm. in length. The costal grooves are visible and pigment in a broad band extends over the dorsal surface of the neck and anterior half of the trunk.

Larva 9.5 mm. Figure 9.

The eye is now pigmented. The mouth is well defined and the gular fold projects a little over the base of the gills; these now appear as three points on a common base. The anterior limbs have a length of .5 mm. the posterior of .25 mm.; the latter are now attached on the line between yolk and body, consequently the anus lies in the free part of the body posterior to the yolk.

The accumulation of fluid between the egg and the innermost envelope has increased the diameter of the egg and envelopes together from 4.5 or 5.5 to 6.5 or 7 mm. This is not due to a thickening of the walls of the spheres but to such a distension of the inner one that yolk and larva together occupy only the lower two-thirds of the cavity. No further enlargement of the cavity occurs, consequently the larva becomes more and more closely coiled as its length increases, for the diminution of yolk that soon becomes noticeable does not compensate for the increased bulk of the larva.

The rotation ascribed to cilia on the ectoderm has been noticed in some larvæ of this stage of development, but in none later.

Although the blood is not yet red a hand lens will reveal the following plan in the circulation over the yolk mass, the vessels appearing as colourless lines against the white background of the yolk; the direction of flow can be followed as the corpuscles are easily visible. Small arteries metamerically arranged run laterally over the yolk; they branch and anastomose in such fashion that a network two or three meshes in width is formed between the margin of the body above and the vein in which they terminate ventrally. (Figure 9). Usually there are two such veins at first, a right and a left; at a variable time in later development one disappears, as is usual in Urodeles. Sometimes the anterior part of the network on one or both sides collects into a separate vein, making for a time three or four separate trunks that unite just posterior to the heart. Sections show these vessels all lying, as might be expected, in the splanchnic mesoblast which has ere this completely surrounded the yolk.

Larva 10.5 mm.

At about this length sections show for the first time perforation of the gill pouches, two only—the first and second—ever become perforate. The anterior limbs show the first indications of digits in that their extremities are flattened and show a terminal notch and a shallow groove leading to it on each side. The posterior limb is not appreciably flattened.

Larva 11 mm.

Each division of the anterior limb above noted is showing two tubercles, the four digits being thus indicated. The posterior limb has exchanged its rounded contour for an angular one but no notches or grooves appear on it.

Larva 12 mm. Figures 10 and 11.

The digits of the posterior limbs appear as five tubercles, the second and the third of which are the most prominent.

Larva 16 mm. Figure 12.

The posterior limbs are growing the more rapidly; they are now as long as the anterior ones—2.5 mm.—and much stouter. Both pairs are provided with well developed toes. The gills have developed greatly each being two to three mm. long and consisting of a central stem with six or eight side branches. Considerable variation in the length of the gills is found in larvæ from different broods in what is otherwise the same stage of development, the shorter gills having also the shorter side branches. Some diminution of the yolk mass is for the first time noticeable, its vertical depth having lessened, though the attachment to the body is still along 3.5 mm. of the ventral surface. Sections show that in larvae from 9 mm. onwards the body walls are actually complete, but the more ventral part of the mesoblast is so much thinner than the dorsal and the line along which the two parts meet is so sharp as to produce in the entire larva the appearance of having body walls developed only over the upper part of the yolk mass. At this stage rather more than the dorsal half of the yolk is covered by this thickened part of the body wall. The pigmentation typical of the adult is complete.

Larva 17.5 mm.

The posterior limb has outgrown the anterior, the lengths being 3 mm. and 2.75 mm. respectively. The length of the gills is reduced to 1.75 mm. or less. The yolk mass has so diminished as to be almost covered in by the thicker parts of the body wall, only a portion 2.5 mm. long and .5 mm. broad projecting slightly in the mid-ventral line.

Larva 20 mm. to 25 mm. Figure 13.
(just on the point of escaping from the mucous envelopes.)

The anterior and posterior limbs are 3 mm. and 3.5 mm. long respectively. The yolk mass is almost entirely covered in. The gills are

reduced to a few small points not over .25 mm. long. Sections of several larvæ of this general stage but differing slightly in development show that both the gill slits become closed before escape from the envelopes occurs, the second one being the first to close.

In their development the digits of the posterior limb but partly bear out the expectations of Cope ('89). He would regard Hemidactylium with its posterior foot possessing only the first four digits as having for permanent form that which is larval in Plethodon. Dealing with *P. cinereus* he finds the adult has the outer digit longer than the inner, but in younger specimens it is shorter and in his youngest (18 mm. only but having already lost its gills) it is but a minute tubercle, "and in a little earlier stage cannot but be wanting though this I have not seen." On this point fifty-one larvæ were examined covering twelve stages, beginning with larvæ of 11 mm. long and ending with the smallest found living alone, its length being 23 mm. In larvæ of 12 mm. the whole five digits appear at once and the fifth is no less prominent than the first. There follows a brief period—*viz.* until the larva attains a length of 16 mm.—in which the rate of growth of the fifth digit as compared with that of the first, varies; of twenty-nine specimens within these limits the first exceeded the fifth in sixteen, the fifth exceeded the first in three, and in ten they were equal. (Seven broods are represented in this, in four of them only were all the larvæ alike on this point). This period alone is in accord with the argument of Cope. In all larvæ over 16 mm. (thirteen in number representing four stages) the external toe was longer than the internal.

EFFECTS OF TERRESTRIAL DEVELOPMENT.

The influence of a purely terrestrial development is seen chiefly in the following points.

The large amount of yolk in the egg in proportion to the size of the animal, a point already dealt with.

The yolk mass retains its globular form until late in development (larvæ of 13 to 15 mm.), when the absorption of its substance causes it to become fusiform. In aquatic larvæ the mass early elongates to produce a slender body capable of rapid darting movements, a necessity not laid upon the yolk in the inactive larva of Plethodon.

The development of limbs occurs early. Traces of the anterior limbs are distinct in larvæ of 5 mm. and of the posterior limbs in those of 6 mm. In Amblystoma these traces appear in larvæ of 7.5 mm. and 13 mm. respectively. From the large size of the posterior limbs

in his larvæ Montgomery ('01) was led to suggest the possibility of their development before the anterior limbs, contrary to the usual condition in Urodeles. This proves not to be the case, though they do appear earlier than usual and grow more rapidly.

The development of gills is retarded. No trace of them as separate points is found until the larva reaches a length of 8 or 9 mm.; in Amblystoma the same occurs at a length of 6 mm. Looking at limbs and gills together the contrasts are marked; when Plethodon first shows external gills its posterior limbs have been for some time distinct; when Amblystoma first shows posterior limbs its gills are 1.25 to 1.5 mm. long and plentifully branched.

It is of general occurrence that the gills of such amphibian larvæ as have no free aquatic life are proportionately longer than those of larvæ that do. The condition in Salamandra atra as described by Chauvin ('77), shorter and stouter gills being assumed when aquatic life was forced on the larva, is typical. This obtains also in Plethodon, the filaments as well as the main trunks of the gills being much longer but much less numerous than in aquatic larvæ of the same size, *e.g.* those of Amblystoma. Such marked reduction in the number of filaments does not occur among all Urodele larvæ of non-aquatic development. In aquatic larvæ the gills are largely directed backward to afford as little resistance as possible to passage through the water; in Plethodon they spread out as widely as possible, the direction being a matter of indifference. The point of importance is that they apply themselves to as much of the mucous envelope as possible and so place themselves where they can best obtain a supply of oxygen.

Plethodon has neither the balancers nor the adhesive discs common among other amphibian larvæ.

The body of a Plethodon larva is from the first that of a terrestrial animal, cylindrical and without trace of median fins. Like the larva of Autodax (Ritter and Miller '99) it has lost the swimming instinct; when placed in water it sinks to the bottom and falls on one side; often indeed it twists its body and writhes violently but such movements never result in any progression or even in temporarily regaining balance. They seem to be only the wriggling that occurs periodically within the egg envelopes; it can always be induced by any stimulation of the larva.

The complete darkness in which the development of Plethodon takes place is partly responsible for peculiarities in colouring. Pigment is entirely lacking in the egg nor does it appear in the larva until a length

of about 6 mm. is reached. When pigmentation does begin it rapidly assumes the pattern and colours of the adult; this is evidently related to the fact that when the larva issues from the egg envelopes it at once assumes the habits and habitat of the adult. The lack of a free larval life differing from that of the adult renders unnecessary the distinctive larval colouration so common among Amphibia. At the same time the surrounding darkness renders it safe for the larva to receive the colouration of the adult. The reason why the larva of Autodax (Ritter and Miller '09; Ritter '03) should under somewhat similar circumstances show a darker colour than the adult may lie partly at least in the fact that its development occurs in dimly lighted cavities and not in absolute darkness as does that of Plethodon.

Amblystoma (or Spelerpes), Desmognathus, Plethodon, and Autodax form an interesting series the members of which, taking larval and adult life together, show an increasing adaptation to terrestrial life. The first is terrestrial only in adult life and returns to the water to lay its eggs. Desmognathus (Wilder '99) begins its development on land like Plethodon but near the water; it leaves the egg while yet a larva completing its development in the water and accordingly stands as an intermediate between Amblystoma and Plethodon. The habitat of the adult Desmognathus, never far from a stream, also shows a less degree of adaptation to terrestrial life than that attained by Plethodon whose habitat bears no relation to bodies of water. On the other hand Autodax is less dependent on moisture in its surroundings even than Plethodon. I have had adult Plethodons die in confinement from conditions of no greater dryness than those described as supported by Autodax (Ritter and Miller '99). Moreover the prehensile tail, the greater ability in leaping and more intelligent use of the power would also indicate more perfect adaptation to terrestrial conditions than has been attained by Plethodon. As larva, Autodax has entirely lost the fringed condition of the gills; Plethodon still retains these fringes but in such varying degrees in different individuals as to indicate their decadence as organs. The degree of parental care of eggs and larvæ increases regularly in the series Amblystoma, Desmognathus, Plethodon and Autodax.

Experiments.

To determine what part the mother may play in the incubation various plans of development under artificial conditions were tried. If removed from their natural surroundings and suspended in air the eggs show signs of rapid loss of moisture and the larvæ soon die. To obtain an atmosphere as moist as that in which they naturally hang, clusters

of different ages were suspended over water, each cluster in a wide-mouthed bottle the cork of which had two shallow grooves cut down the sides to admit small quantities of air. The bottles were kept in a cellar where the temperature was practically the same as that of the natural situation of the eggs. In all the clusters development proceeded without interruption, in some cases for as much as twenty-five days when an impending absence from the laboratory rendered it necessary that the experiments be terminated and the larvæ were fixed. About eight per cent. of the larvæ always die under this artificial incubation, in some bunches no deaths at all occurring, in others several. This is quite striking, for no unfertilized eggs or dead larvæ were ever found under natural conditions. Three things may account for this; injury in conveying to the laboratory, the growth of mould during incubation, and lack of the normal increase of fluid between the egg and the inner envelope. Mould on the eggs although never encountered under natural conditions sooner or later makes its appearance on all eggs reared as above described. It does not however always have an early fatal effect, for all the larvæ in a bunch have been found alive after having been quite obscured for two days by a growth of mould. The increase of fluid between egg and envelope can hardly be said to occur under these artificial conditions and presumably some pressure is exerted upon the larva. These things suggest that the female may in some way prevent the growth of mould on the eggs and also supply them with moisture and an endeavour was made to test this in the following way. In a wide-mouthed jar pieces of the log in which the eggs were found were arranged to form a little chamber in which the female was placed and the piece suspending the eggs then added as a roof; more fragments were placed upon this and the surface covered with a little humus and moss, a few drops of water were occasionally sprinkled on the surface. Jars so prepared were kept under the same conditions as the bottles previously mentioned for three weeks, by which time mould would certainly have appeared on eggs kept in bottles, but none was found, and the amount of fluid surrounding the larva was as great as natural. In a subsequent set of experiments it was found that even thoroughly wetting the cluster two or three times a day, in addition to keeping it over water as before, would not suffice to bring about the normal accumulation of fluid. This was only obtained by allowing the lower end of the cluster to remain in contact with the surface of the water in the bottle for about twelve hours out of each twenty-four.

No final statement should be based on such scanty experimental evidence but such weight as it has is entirely in support of the supposition that the mother in this case—and presumably in similar cases reported

among Urodeles—does along the lines mentioned actively promote the welfare of her brood.

In those last mentioned and in other experiments in which the clusters of eggs were entirely immersed in running water it was noticeable that the mucous envelopes would imbibe readily a small quantity of water and swell slightly in consequence, but the limit to this process was usually reached within the first half hour, nor did any second period of imbibition occur. No softening of the envelopes was to be noted even after constant immersion for three weeks. These qualities of the mucus mark it as different from that of most amphibian spawn which continues to absorb water and to soften until the larvæ escape. They probably are to be considered adaptations to prevent rains of even most unusual duration from softening the mucus and turning loose the larvæ prematurely.

The bottle method before described was used to test the possible effect of light upon development. Several bunches were exposed to daylight, which however never became direct sunlight, while others of the same stage of development were kept in entire darkness as controls, the temperature being in each case, within limits of variation of three or four degrees, the same. At the end of twenty-five days no difference in the degree of development of the two lots was to be detected. The lack of pigment in the egg might be put forward but the whole explanation cannot rest on this for early in the life of the larva pigment appears in the skin and rapidly increases in amount; and in the experiment this pigment was present for the last twenty days. In the experiments of various investigators to determine the effect of light upon growth Amphibian larvæ in aquaria have frequently been used; in which case the oxygen and part of the food have been derived from the water. Since both these things would be more abundant in the better lighted aquaria, factors must be allowed for, whose exact influence is unknown. In the present case the food and oxygen factors are the same for both sets of larvæ and the uncertainty of result due to several factors varying simultaneously is lacking.

Points Arising Out of the Lungless Condition.

In Amphibia generally the function of the skin as an organ of respiration accessory to the lungs has long been recognized. Later Maurer ('98) drew attention to the advantageous position for purposes of respiration held by the capillaries of the bucco-pharynx, many of them being situated in the epithelium itself. To these localities therefore the attention of investigators was naturally directed in seeking the means which

would compensate for the lack of lungs. The conclusions reached were not uniform, some investigators accepting both skin and bucco-pharynx with more or less of the œsophagus as sharing with something like equal importance in the respiration, others concluding that the skin is no more efficient in respiration in lungless salamanders than in those with lungs. Some examinations of Plethodon along these lines was in progress but ceased when the paper of Seelye ('06) on the Circulatory System of Desmognathus came to hand for the points already dealt with showed that the conditions in Plethodon would be but a repetition of those in Desmognathus: and would lead to the same conclusion, namely that as an organ of respiration the skin is much more important in lungless than in lunged salamanders. The same paper also gives a sufficient review of the question and its literature so all that will be attempted here is to bring forward three additional pieces of evidence in support of the above conclusion.

First, as noted in the paper itself the value of the cutaneous capillary network for respiration will depend upon the permeability of the membrane through which diffusion must take place. The fact that this membrane is the epidermis and not the entire skin renders exact experimentation impossible. Nevertheless the experiments performed by Seelye indicate that the entire skin of lungless forms is much more permeable than that of those with lungs and it would be strange to urge that the difference in the cutis accounts for this for it is the lungless forms that have the thicker cutis. This point of structure is, according to Seelye, the only one of general distinction between the skins of the two types in question; a conclusion that it is hard to understand unless it is due to the presence of two European forms with lungs among those examined. A more trustworthy comparison would be one between forms that live in the same environment and in the case of Plethodon this is possible, for small specimens of *Amblystoma punctatum* and of *Diemyctylus viridescens* in its terrestrial stage of life are occasionally found along with *Plethodon cinereus*. The skins of specimens so found and of adult Plethodons of about the same length were examined all being submitted to the same procedure, *viz.* the entire animal was fixed in Zenker's fluid with the usual after treatment, then from similar regions of head, trunk, and tail, pieces from dorsal, ventral, and lateral aspects were sectioned perpendicularly to the surface. The only considerable and constant difference in the epidermis is one of thickness. To estimate this correctly several measurements in micra were made from each piece of skin and these were averaged. Finally the figures thus obtained for each of the areas investigated were averaged to obtain a figure that would fairly

represent the average thickness of the epidermis over the whole body. These averages were 22.4 micra for Plethodon, 46 micra for Amblystoma, and 44 micra for Diemyctylus. Consequently as regards this factor unless we assume a most improbable thing, namely that the epidermis of Plethodon is of a material less permeable than that of Amblystoma and Diemyctylus, we must conclude that of the three the skin of the lungless form Plethodon is fitted to be by far the best respiratory organ.

Second. The bucco-pharyngeal respiration is indeed established very soon after escape from the egg yet even in the adult it may be suspended for a considerable time without serious inconvenience. When confined in a glass vessel the animal will occasionally rest the ventral surface of head, neck, and more or less of the trunk against the glass; the adhesion between the glass and the moist and sticky skin is sufficient to prevent the respiratory movements. I have frequently seen this continue for two or three hours and have found the position of the body apparently unchanged after even much longer intervals, but in these cases observation not being continuous it is possible that the animal may have moved for a time and then resumed its exact original position, but such a thing is unlikely.

Third. There is a period of a few days in the life of a Plethodon during which such respiration as occurs at all must take place through the skin. This is the period just prior to the escape from the egg envelopes. The gills attain their maximum of development—a length of 3 mm.—in larvæ of about 15 mm.; after this they decrease in size and for some time before the escape of the larva are reduced to small points not over .25 mm. in length. No movements of the ventral pharyngeal wall are to be observed at this time so it cannot be that there exists a mode of respiration similar to the aquatic pharyngeal respiration noted in *Diemyctylus*, both *viridescens* (Gage '01) and *torosus* (Ritter '97), the fluid within the egg envelope playing for Plethodon the part of the surrounding water for Diemyctylus. Consequently whatever oxygen is used by the larva must be absorbed through the skin. The amount of oxygen required by the larva may well be less than that required by the free-living animal yet it is by no means an inconsiderable fraction of it. The muscular activity in the beating of the heart and the wriggling of the larva within the envelopes that occurs not infrequently is probably little less than that of the free-living animal, which though capable of active movement rarely indulges in it, forming in this respect a marked contrast to Diemyctylus. If the larva can carry on its respiration through its skin alone, hampered as it is by the surrounding fluid and envelopes,

it is difficult to escape the conclusion that in the free-living stage as well the skin must be an important factor in respiration.

The development of gills in the first place is governed by the same necessity as exists in other Amphibia; sections show that the beginning of their degeneration coincides with the skin becoming sufficiently developed for the circulation in it to become somewhat extensive; and that their diminution keeps pace with the elaboration of the cutaneous circulation, just as in most Amphibia it accompanies the increasing activity of internal gills or lungs.

EARLY DEVELOPMENT AND DEVELOPMENT OF INTERNAL ORGANS.

Studies in these fields have revealed several points of interest which it is proposed to consider in a future paper.

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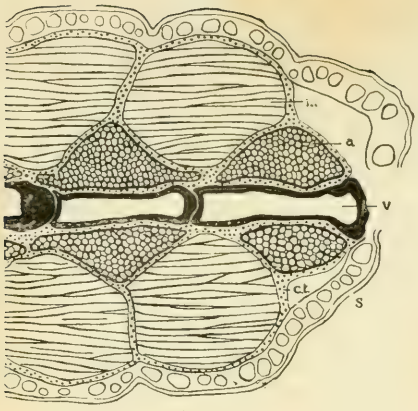

Fig 1

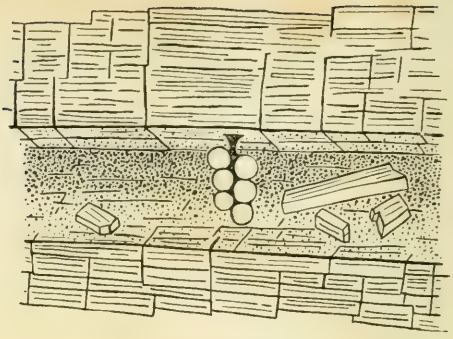

Fig 2

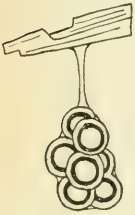

Fig 3

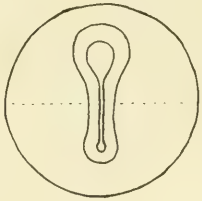

Fig. 4

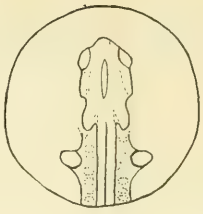

Fig. 5

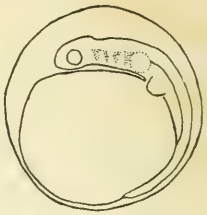

Fig. 6

Fig. 7

Fig. 8

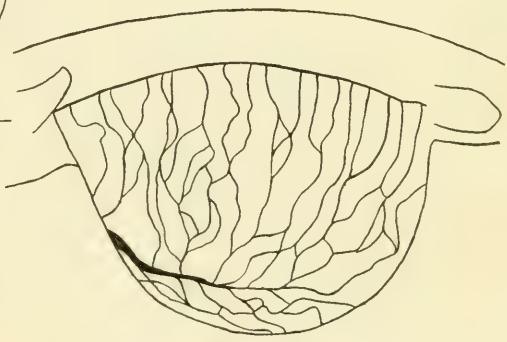

Fig. 9

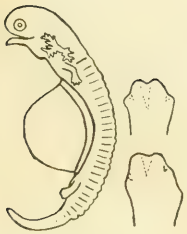

Fig. 10

Fig. 11

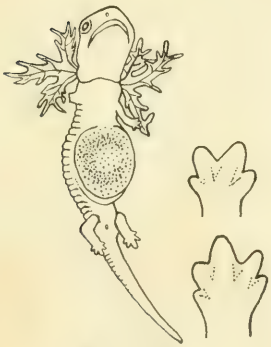

Fig 12

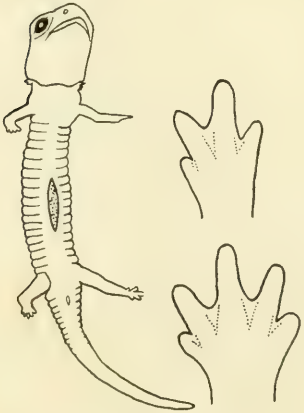

Fig. 13

Fig. 14

ILLUSTRATIONS.

Figures 1 and 9 are camera lucida drawings, 2 and 3 from photographs, 4-8 and 10-14 from projections by Zeiss epidiascope. Figures 4-8 are enlarged to the same extent, which is twice as great as that of figures 10-14. Figures 4 and 5 from eggs of maximum size, 6 and 7 from eggs of minimum size. The outlines of the feet, Figs. 10, 12 and 13, are camera lucida drawings; they are right feet viewed from the dorsal surface under low magnification.

Figure 1. Horizontal section of tail through the proximal wound of an autotomy.
v—centrum of vertebra.
a—perivertebral adipose tissue.
m—myotome.
c. t.—connective tissue.
s—skin.

Figure 2. Cluster of eggs suspended in a large crack in a decaying log.

Figure 3. Cluster of eggs.

Figure 4 Stage 3 mm. Egg viewed from side, the dotted line being the equator of the egg when the latter is in its natural position.

Figure 5. Stage 5 mm Egg viewed from above.

Figure 6. Stage 5.5 mm. Egg viewed from the side. The outline of the mucous sphere was added from a living specimen

Figure 7 Stage 6 mm Egg viewed from above.

Figure 8. Stage 9 mm. Viewed from above, the head and tip of the tail are much bent towards the ventral surface.

Figure 9. Vitelline circulation in larva 10 mm. long.
a—anterior

Figures 10 and 11. Stage 12 mm.

Figure 12. Stage 16 mm. Taken from a small larva, actual size, 14.5 mm.

Figure 13. Stage 20-25 mm Actual size of larva 20 mm.

Figure 14 Specimen from the centre of the same bunch of eggs as that of Figure 13, which is one of the outer larvæ

ON THE ORIGIN OF THE CANADIAN APATITES.

By William Harvey McNairn, M.A.

(*Read 24th April*, 1909.)

I.

Introductory.

1. For more than a quarter of a century the problem of the origin of apatite has occupied a prominent position among current geological discussions. Some of the most interesting questions in the domains of biology, of economic geology, of mineralogy and of geology depend for their solution upon the answer to this important problem. In consequence there have been propounded various theories of extraordinary divergence and irreconcilable dissimilarity. Three of these are alike so plausible and so important that any discussion on this subject is necessarily prefaced by a careful examination and comparison of them and the premises from which they have been deduced.

2. Thirty-five years ago the Norwegian geologists, Brögger and Reusch, were engaged in an exhaustive examination of the deposits of apatite in their country, and in 1872 published their well-known paper.[1] In this they show that all the available facts tend to suggest an eruptive origin. The interest aroused by this work led Harrington to make a careful comparison of the facts as there recorded with those observable in the Canadian deposits. In his paper in the Geological Survey Report of 1877,[2] he points out that while the Norwegian apatites in their mode of occurrence and in their associated rocks have much to remind one of the Canadian deposits, there are many points of dissimilarity which would lead us to believe that however the Norwegian deposits have been formed, the Canadian are certainly not eruptive. However the eruptive theory has not been without its Canadian supporters. For instance, in a foot note in Ells' report[3] Selwyn remarks: "My own examination of the Canadian apatite deposits has led me to a conclusion respecting their origin corresponding with that of the Norwegian geo-

[1] Brögger—Reusch—Zeits. der deu. Ges. 3:646.
[2] Harrington—Minerals of Apatite Veins, Geol. Soc. Can 1877-78 Q.
[3] Ells. Geol Soc. Can. N. S 4:93.

logists. They are clearly connected for the most part, with the basic eruptives of Archean date."

3. In 1876 Sir William Dawson presented a paper to the Geological Society of London[4] in which a new and novel theory was developed. The Laurentian gneisses were altered sediments; the deposits of apatite occurring in proximity to them were also to be considered as metamorphosed clastic rocks, and not only so but they are derived from depositions of organic remains. Around the hypothesis thus propounded has raged one of the most vigorous discussions in the later history of the science. Once it is proved that we have undoubted remains of organic life in strata thus low in the geological series an important biological fact has been attained.

4. Still another theory was brought forward by Professor Boyd Dawkins, in 1884.[5] He concluded that the deposits are in the form of true veins and that the phosphoric acid is brought from the deeper seated rocks by means of hydrothermal action. But, according to Bell[6] the almost universal presence of phosphoric acid in igneous rocks, coupled with its marked power of segregation, suggests a much more obvious source. In the discussion arising from Dawkins' paper, a modification of his vein theory was suggested by Kinahin. In this he endeavoured to account for the occurrence of apatite in a corresponding manner to that of phosphorites by supposing the action of phosphoric acid on a calcite vein stone.

5. These three theories so radically different and so irreconcilable can each lay claim to many supporting facts and it becomes of importance to classify and compare these. It is evident that they may be grouped into five separate divisions as follows:

I. The evidence supplied by the associated rocks, their chemical composition and geological form.

II. The evidence supplied by the geological form, veined, bedded or eruptive of the deposits themselves.

III. The evidence supplied by the chemical and physical peculiarities of the apatites.

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[4] Dawson—Quart. Jour. Geol. Soc.
[5] Boyd Dawkins—Manch. Geol. Soc.
[6] Bell—Eng. Mining Journ.

IV. The evidence supplied by certain associated minerals whose uniform presence is thought to have an important bearing on the subject.

In the following pages each of these classes of evidence is considered in detail, adding to the facts already published such new material as appears to throw additional light on the question.

II.

Evidence of the Rocks.

6. All the Canadian apatite deposits occur in those series of rocks known as the Grenville and Hastings. When these were first mapped, and for many years after, they were considered a part of the Laurentian system. They are enclosed by the gneisses of "the basement complex" and are difficult to differentiate from each other and the surrounding rocks, but it became increasingly evident that below the lowest of these and above the "fundamental gneiss" there was a very definite break. The geologists of the then newly developed uniformitarian school believing they saw in the schistosity of the granite gneiss the marks of an original bedding naturally concluded that above the unconformity the clastic nature of the rocks was beyond dispute.

7. The reaction from this extreme uniformitarianism led to the claim that not only the "basement complex," but also the Grenville and Hastings are eruptive. Since then the general trend of geologic opinion, in the light of increasing data, has been turning again in the other direction.

8. One of the most recent investigations into the natures of the Grenville and Hastings rocks was that undertaken by Barlow and Adams and described in the Canadian Geological Survey Report for 1896.[8] These investigators made a careful examination of the area of contact between these two series and the true Laurentian, and have given their reasons for believing the Grenville to be clastic. "In the region under examination, it comprises a great development of limestones, with which are associated certain gneissic rocks whose minute structure and appearance mark them as highly altered sediments."[9] The reasons which led them to these conclusions were as follows:

(a) The investigations of Dr. Adams showed these rocks to be very different from the prevailing types of granitic and dioritic gneisses.

[8] Barlow and Adams, Geol. Surv. Can. Summary. 1896: 45

[9] Idem. p. 47.

(b) Various analyses made indicate in most instances a composition almost identical with that of ordinary shale or slate.

(c) Under the microscope the appearance and arrangement of the component minerals are often suggestive of contact zones bordering granites.

(d) Almost invariably these rocks are associated with limestones. Their conclusion as to the Grenville series was that "the relations are such as to suggest that in the Grenville series we have a truly sedimentary group of strata which has sunk slowly down into, and has been invaded by great intrusions of igneous rocks of the Fundamental gneiss, when these were in a molten or plastic condition."[10]

9. No line of demarcation is observable between the Grenville and Hastings, although the limestones while in the latter were less altered, yet the change is so gradual that it is often impossible to determine in a given case to which series it should be referred. "Finally," they conclude, "in the region in question, the Hastings series probably represents the rocks more nearly in their original form, and that the same rocks when invaded, disintegrated, fretted away, and intensely altered by and mixed up with the underlying gneissic magma into which they had sagged down became identified with the Grenville series. In short we have in the Grenville series an extremely metamorphosed portion of the Hastings series."[11]

10. Now it has been observed that in the rocks below the Cretaceous and above the Devonian there is practically no phosphoric acid. This, Shaler suggests,[12] is to be explained by the absence of those animals whose shells contain phosphorus. Below the Devonian the percentage appears to increase as we descend in the series until the maximum is reached in the Grenville with its beds of Apatite.

11. This then is the geological horizon in which the apatites occur. Among metamorphosed rocks whose clastic origin is yearly becoming more definitely proved; in a series whose position at the foot of an uninterrupted scale is gradually being settled; and below that line down from which the remains of phosphorus-bearing animals steadily increase in quantity, the theory of their organic origin is one that admits of no *a priori* objection.

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10 Idem. p. 49.
11 Idem. p. 48.
12 Intro. to Penrose Phosphates.

III.

EVIDENCE FROM THE NATURE OF THE DEPOSITS.

12. In the search for evidence as to the origin of apatite, one naturally commences by a careful examination of the tectonic characteristics of the deposits themselves. If on the one hand these are invariably in the form of undoubted veins or dykes or if on the other they occur without exception interbedded with evident clastic rocks, the problem of their origin would be beset with few difficulties. This phase of the question naturally occupied a large proportion of the attention of the earlier investigators. Unfortunately the circumstances of their occurrence were so varied that no uniformity of deduction was possible.

13. Brögger and Reusch noted the fact that the apatite deposits maintain their course quite irrespective of the nature or structure of the country rock. Also, many of the deposits are coarse grained at the centre becoming finer towards the outside, a peculiarity of trap dykes. Where this is so prominent as to give rise to a roughly banded structure it could readily be explained as the result of slow cooling of such an intrusive mass. Again the deposits frequently contain large irregular masses of foreign rock, quite different from that of the surrounding strata, and supposedly brought up from greater depths. In short these authors decided that all deposits in their country are eruptives, having the characteristics of dykes.

14. Harrington in commenting upon this conclusion points out two ways in which the Canadian deposits differ from those described. In the first place the Canadian apatite deposits are clearly influenced by the surrounding strata. It is among limestones for instance that the deposits are calcareous. In the second place the granulated structure, so important in showing the deposits to be dykes, is scarcely ever observed in Canadian examples.

15. The theory that the Canadian deposits of apatite are in the form of true veins has been vigorously supported by Bell in 1885[13] and Dawkins in 1889.[14] Our attention was called by Dr. Bell to the fact that phosphoric acid is a constituent of nearly all rocks, and that the small quantity which is present is offset by its extraordinary powers of segregation. Professor Boyd Dawkins referred to the strikingly

[13] Eng. Min. Jour. 1885 ∃
[14] Man. Geol. Soc. 1889.

veinlike appearance of many examples and also to the similarity of the concurring minerals to the ordinary veinstones. Many of the deposits have very much the appearance of veins, but Shaler[15] has pointed out, that in such cases the veins are very sharply contrasted with the country rock and are not dependent upon it for their component minerals. From this he deduces the important rule that such veins have been deposited in previously formed crevices.

16. It does not necessarily follow, however, that the mineral was not originally a clastic deposit, even though examples of evident vein occurrence are to be found. As has already been mentioned, the rocks of the district show such evidence of metamorphosis that none of them are in their original condition. Again there are not lacking instances of more recent, and in consequence more evidently organic phosphates occurring in deposits closely resembling veins.

17. However, as is very evident, there is no unanimity of opinion to be reached by an examination of the deposits. The various observers have had the same series of rocks under examination, but have reached conclusions absolutely different. Penrose's deduction after an examination of the whole region is that the deposits are "mostly in irregular masses."[16] Sterry Hunt in '84[17] described its occurrence as interbedded in veins. In the latter form the mineral is much more impure and mixed with foreign material. When in bedded form the deposits show many of the characteristics of true beds and in fact often present striking analogies in structure to the coal measures.

18. A famous locality for apatite is the Smith and Lacy mine near Sydenham, Ont., now operated for phlogopite by the General Electric Company. This was visited by the writer as a typical example of the so-called vein occurrence of apatite. This mineral, originally the most abundant in the vein, has almost disappeared. The deposit occurs in a rusty gneiss and runs in a north-east direction. The vein itself which is about ten feet wide goes downward almost vertically.

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[15] Intro. to Penrose "Phosphates" p. 38.
[16] Penrose, p. 37.
[17] Trans. Am. Inst. C. E. '84.

IV.

EVIDENCE FROM THE CHEMICAL CHARACTERISTICS OF APATITE.

19. "Scarcely any other economic mineral occurs in such diverse forms as mineral phosphate."[18] In the guano and bone beds we see the substance of modern or recent deposition and clearly organic. The nodular phosphates from which most of the fertilizers are made give ample indication of their origin in the fragmentary fossils which they contain. The presence of phosphoric acid in some phosphatic limestones is less easily explained, but it is conceded to have been due to the numerous animal remains which would accumulate at the bottom of the teeming Silurian seas.

20. When we turn our attention to the phosphorites which differ from the above in a comparative fixity of composition, the problem of referring them to their origin becomes much more difficult. This mineral occurs in irregular crevices and cavities in rocks of various ages and kinds, very frequently in limestone regions it occurs also as an incrustation on the sides of caverns. To explain the presence of the phosphorite two hypotheses have been proposed; firstly "the hypothesis of ascending water," secondly, "the hypothesis of descending water."

21. According to the hypothesis of ascending water, the presence of phosphorus is accounted for by the equally hypothetical occurrence of phosphides in the abysmal depths. Water coming in contact with these at high temperatures causes their dissociation and as the solution reaches points nearer the surface it attacks any limestone present and precipitates calcium phosphate on the surface. Two facts militate against this hypothesis. In the first place the deposits are usually shallow and superficial. In the second place as Filtol has pointed out[19] when they are fully worked out they do not show any necks or leads of phosphorite pointing towards a deep seated origin.

22. The hypothesis of descending water accounts for the phosphorites on the supposition that they were originally in a bedded form and derived from the animal remains. These beds acted upon by thermal water, were dissolved or leached away and the calcium phosphate was reprecipitated in a purer form in caves and crevices. This according to

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[18] Penrose, p. 10.

[19] Recherches sur les phosphorite du Quercy—Annales sci. geol. 7; 1-120, 1876.

Dieulafait[20] offers the most reasonable explanation. Thus the absence of any stringers of phosphates along joint planes, and the absence of a marked increase of action towards the bottom of the deposits is accounted for. Also it suggests a more natural origin for the cavities in which the phosphorite is deposited. It is not necessary to suppose that these are the result of the thermal waters themselves, but they are conceived as being open before the waters came. The theory also accounts for the presence of gypsum and iron ore as referred to subsequently. Another point of interest is the fact that the deposits are richer in phosphoric acid near the walls. It is only when the solution of phosphoric acid becomes neutralized that the calcium phosphate can be deposited, and the zone of precipitation is that point of contact between the solution and the limestone.

23. It would thus appear that all known facts tend to prove that the phosphorites—that form of phosphate which with the exception of apatite, shows the least indication of organic origin,—are like all other forms the product of the decay of organisms. We may judge from analogy that all deposits of phosphate in sedimentary rocks are secondary and have a similar origin.

24. Thus, as has been pointed out by Dawson, all deposits of phosphate at present in process of formation are of unquestionably organic origin. Those of earlier periods, while not so obviously so, still have the evidence of the included fossils. But the very earliest possess no indications, either in themselves or by means of fossils, of an organic origin. However, when we consider the beds in process of deposition, the earlier formations, and the very oldest, it is apparent that we have, with some considerable hiatuses, a series. If these breaks can be bridged a chain of life is established.

25. The fundamental step in the establishment of such a series is to account for the presence of phosphoric acid. The amount of phosphorus in animal tissue is comparatively small, and yet there are beds of very great extent which have become phosphatized by decaying animal matter. De Lapparent had early pointed out that living organisms possess the power of appropriating to themselves such elements as are necessary for the maintenance of life, even though the proportion of these elements in the surrounding medium be imperceptible traces. The application of this fact to the case of phosphoric acid was made by Carnot. A number

[20] Origine et modes de formation des phosphates de chaux en amas dans les terrains sedimentaires. Leur Unison avec les minerals de fer et les argiles des terrains siderolitiques par M. Dieulafait Ann, de Ch. et de Phys. 6: 5: 204.

of mussels were used in the experiment. Their bodies yielded on an average 14 grms. of ash each. They were left for 50 days in a 5 li. flask with a ground stopper. In this was put 1,500 c.c. seltzer water containing 45 grms. precipitated tribasic calcium phosphate. On incineration, they yielded 314 mgr. of ash, or 147 mgr. more than in the ordinary state. This ash gave the following analysis:

Tribasic calcium phosphate	86.88
Calcium carbonate	11.18
FeO & Al_2O_3	1.91
	99.97

26. In another experiment he used wood, 100 parts of which gave 0.44 ash, containing 0.00018 P_2O_5, or 4.07% of the total ash. After being seven months in a closed flask containing 5 grms. powdered calcium phosphate and 2 grms. ammonium carbonate in distilled water, 100 parts gave 0.33 ash containing 7.75% of phosphoric acid. On repeating the experiment using seltzer, the proportion of ash was 0.66 giving 24.25% of phosphoric acid. These facts would appear to have a most important bearing on the matter. For we have here an explanation of the fact that although animals and plants contain only a small percentage of phosphoric acid, their accumulated remains form vast masses of phosphates.

27. While these arguments are of weight in the consideration of rock phosphates, we are met with difficulty when we turn our attention to the apatites which are essentially fluophosphates or occasionally, chlorophosphates. So great is this difficulty that M. Lasne offered as his elucidation that the deposits of phosphate are practically all fluophosphates and supposed them to be due to precipitation in land-locked, shallow seas of the fluophosphates in solution. This was found to be an untenable position, and we were forced again to look for a new explanation.

28. Here as in the previous problem the researches of M. Carnot prove of value. He found [21] that fossil bones, composed essentially of calcium phosphate when allowed to stand in water containing a little fluoride in solution will gradually appropriate a small proportion of the fluorine especially if there be an evaporation with a simultaneous addition of fresh water.

Further,[22] he showed that calcium fluophosphate is much less soluble than the phosphate, and that if a mixture of phosphate and fluophosphate be treated with water, the insoluble residue contains a

21 Ann. des M. '93, 1; 185.
22 An. de M. 9—10 : 163.

much larger proportion of fluorine than the soluble part. Finally he showed [23] that the water of the Atlantic Ocean contains 0.822 grm. of fluorine or 1.687 grm. Ca F 2 per cubic metre.

29. It is thus abundantly evident that under certain circumstances calcium phosphate has the power of absorbing fluorine to form fluophosphate. It remains to be shown that such a process is actually taking place in nature and that colour is lent to the theory that our deposits of calcium fluophosphates were produced from earlier deposits of phosphate by a subsequent process of fluorination.

30. Again we turn to the illuminating researches of M. Carnot. A preliminary analysis of modern human bones gave him [24] :

	I	II
$3\,Ca\,O\,P_2\,O_5$	87.41	64.63
$Mg_3\,P_2\,O_5$	1.57	1.97
$Ca\,F_2$	0.35	0.88
$Ca\,Cl_2$	0.23	0.44
$Ca\,C\,O_3$	10.18	21.10
$Fe_2\,O_3$	0.10	.....
$Si\,O_2$	.....	0 75
$Fe_2\,P_2\,O_5$	.....	9.63
	99.88	99.50

in both of which the proportion of fluorine was small compared with that of apatite.

31. This was followed by a series of analyses of fossil bones of various ages. The proportions of fluorine in these have been grouped in scale of increasing age as follows [25] :

Geological Terrain.		Ratio between % of F in bone and Apatite.	average	Ratio between % of $P_2\,O_5$ & F in bone.	average
Modern		0.058	0.058	193.10	193.10
Quaternary		0.360	0.360	31.30	31.30
Tertiary	Pliocene	0.580	.....	19.20	.....
	Miocene	0.610	0.620	18.30	18.15
	Oligocene	0.590	.....	18.90	.....
	Eocene	0.700	.....	16.00	.....
Secondary	Cretaceous	0.920	.....	12.20	.....
	Jurassic	0.910	0.907	12.30	12.40
	Triassic	0.890	.....	12.60	.....
Primary	Permo-carboniferous	1.060	.....	10.50	.....
	Devonian	0.980	0.993	11.40	11.30
	Silurian	0.940	.....	12.00	.....
Apatite		1.000	1.000	11.21	11.21

[23] An. de M. 9—10 : 175.
[24] Carnot, Os modernes et os fossiles—An. des Mines 9; 3; 164. 1893.
[25] op. cit. p. 182.

Comment is scarcely necessary, but when we remember that the organic remains of the oldest fossiliferous strata contain a very high percentage of phosphoric acid and fluorine we are forced to conclude that in proportion as these deposits of calcium phosphate approach in age to apatite, they approach *pari passu* to its chemical composition.

32. Apatite is a crystallized fluophosphate of calcium of a normal composition of

$$P_2 O , 3 Ca O. \quad \tfrac{1}{3} Ca F_2.$$

which, if reduced to a formula gives us

$$Ca\ 5\ P\ 3\ O\ 12\ F.$$

In such a compound the percentage of fluorine is 3.77 and the ratio between it and phosphoric acid $\frac{F}{3\,P\,2O5} = 0.0892$. Most apatites however contain a certain amount of chlorine. Thus the composition of three specimens from Jumilla, Spain (I) and the Tyrol (II & III) are as follows:

	I	II	III
P 2 O 5	41.71	41.91	41.97
F.....	3.54	3.58	3.63
Cl.....	0.47	0.20	0.03
CaO.....	54.95	55.00	54.65
Fe O.....	tr	0.18	0.48
SiO_2.....	.....	.....	0.80
	100.67	100.87	101.56

The amounts of fluorine called for in the above specimens to complete the standard formula would be:

I	II	III
3.72	3.74	3.74

a considerable excess of that actually found. If we calculate the molecular weights of fluorine in each case which correspond with the given amounts of chlorine we obtain:

I	II	III
0.25	0.11	0.02

which, when added to the amounts actually given by analysis, makes

I	II	III
3.79	3.69	3.65

a much closer approach to the calculated amounts. These results which

have been substantiated by numerous analyses, tend to prove that in the compound represented by the formula:

$$Ca_5P_3O_{12}F.$$

the F may be molecularly replaced by Cl.

33. But even with the light which these facts throw upon the composition of apatite, considerable discrepancies were observed by M. Carnot when he turned to an examination of the chemical composition of the Canadian Apatites. Thus two specimens from Renfrew and Templeton respectively, gave the following analyses:

	I	II
P_2O_5	41.00	41.50
F	2.26	1.26
Cl	0.28	0.37
CO_2	1.50	2.30
CaO	50.84	52.90
MgO	tr	tr
FeO	.....	1.30
Fe_2O_3	4.59	0.22
SiO_2	0.55	0.30
	101.00	100.15

These results were tabulated as follows:

	I	II
F present	2.24	1.26
F corresponding to Cl	0.15	0.20
Total	2.39	1.46
Calculated	3.66	3.76

In order to account for the abnormally small proportion of fluorine both actual and replaced by chlorine, the amount of fluorine which would correspond with the carbon dioxide present was calculated as follows:

I	II
1.30	1.99

which, when added to the previous total, give us

I	II
3.69	3.45

These results, as will readily be seen, approximate with reasonable accuracy to the calculated amounts.

34. The final step in fixing this fact was to produce artificially this replacement by CO 2. To do this he placed a finely powdered portion of a carefully analysed apatite in a hermetically sealed tube with a solution

of sodium carbonate, and subjected the whole to a constant temperature of 160 degrees for six days. The results were as follows:

	I		II	
	before	after	before	after
P_2O_5	41.97	41.78	41.01	40.90
F	3.63	3.60	0.85	0.80
Cl	0.03	tr	5.31	4.60
CO_2	.....	0.11	.....	0.48
Ca O	54.65	54.60	53.44	53.45
MO	.....	.....	0.17	0.20
Fe O	0.48	0.36	0.20	0.05
Fe_2O_3	.....	.....	0.53	0.67
S_1O_2	0.80	0.72	0.14	0.11
	100.56	101.17	101.65	101.26

	I	II	
F replaced by Cl	0.00	0.85	0.80
F replaced by C C_2	0.00	2.84	2.46
			0.41
Total F	3.65	3.69	3.67
Normal F	3.74	3.66	3.65

These analyses not only agree with Carnot's theory, but in the second specimen, a typical chlorapatite one-seventh of the chlorine had been replaced by carbon dioxide.

35. It is evident then that the researches of Carnot throw much light upon the interesting question of the origin of the apatites. He has shown in the first place that decaying organic matter has the property of absorbing phosphoric acid from solutions, even when present in almost infinitesimal proportions. He has shown further that calcium phosphate in turn absorbs fluorine tending towards the stability of the apatite-molecule, and also that this has actually occurred in the case of fossil bones. Further experiments showed that in the apatite molecule, the fluorine is frequently partially replaced by chlorine and carbon dioxide, and that this state of affairs may be artificially reproduced in the laboratory.

36. In short, it may be said when we compare the various phosphates with apatite, that they differ from it in chemical composition just in proportion as their date of origin is distant from the primeval time when the apatite-bearing rocks were laid down. Here and there, it is true, we find among the masses of rock phosphate, crystals of true apatite[26] but they are as minute as they are rare, and are of interest as illustrating *in petto*, the gradual change in composition towards a more and more stable molecule.

[26] Penrose, op. cit. p. 47 and 89, also C. R.

37. The nature of the colouring matter of otherwise colourless minerals, is a problem of general interest to mineralogists, but it has an added interest when we investigate the colour of apatite. Von Kraatz-Koschlau and Wohler, in an interesting research whose results were published in 1899[27] pointed out the very suggestive fact, that the colouring matter in a number of the crystalline minerals examined, was to a greater or less extent organic, among those giving this result were fluorite; barite; celestite; anhydrite; salt; calcite; zircon; smoky topaz; amethyst; microcline; rubellite; topaz and apatite.

38. The European apatites examined were green and violet transparent specimens from Saxony. On being heated they gave off an empyreumatic smell, gradually lost their colour, and exhibited strong colour phosphorescence, which continued only as long as the colour and odour remained. Quantitative analyses made with copper oxide in the usual way gave results as follows:

CO_2	0.003 gr.	0.066%	0.018% C.
H_2O	0.0055 gr.	0.122%	0.014% H.

39. Green apatite from Canada, on being subjected to the same tests gave the organic smell, the greenish fluorescence, but the specimens had a permanent yellowish colour, evidently due to inorganic colouring matter. Their general conclusions were that apatites from European localities were to be referred to that class of minerals whose colour is due to organic material only, while those from Canada were placed by them in the second group whose colouring matter is partly organic and partly inorganic.

40. It was made quite evident from their researches that organic colouring matter and colour-phosphorescence always occur together, It is interesting to note in this connection that some of the phosphorites from Spain show this phenomenon.[28]

41. The apatites from various Canadian localities in the collections of the University of Toronto may be referred to three colour types (a) green from very light to quite dark, (b) flesh coloured from light pink to almost brown, and (c) bluish from light to almost black. Crystals of each of these types were examined for pyro-phosphorescence with the result that the bluish specimens which were the least numerous were found to be practically free of phosphorescence, while the pinkish show it in the

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[27] Tch. min. u. Pet. mitth. 18: 304-447-1889, Von Kraatz-Koschlau and Lothar Wohler — Naturliche Farbungen der Mineralien.

[28] Penrose, p. 54.

most marked degree. In the case of pink and green specimens the colour gradually faded leaving a straw colour which was permanent after the experiment. It would appear, therefore, that the colouring matter of the Canadian apatites is, in the majority of cases, largely organic.

V.—Evidence from the Physical Characteristics of Apatite.

42. In eruptive rocks the microscopic crystals of apatite are among the first to separate and always maintain their clear outlines. Speaking in particular of those in the eruptives of Puy de Dome, Gonnard and Adelphi [29] remark that they nearly always remain intact no matter how its rock has been contorted by violent motion before or during the second stage, and retain their clear outlines.

43. When, however, we turn from the microscopic to the larger examples, a most striking difference is to be noted between those which occur, as in Norway, in pyroxenite without calcite, and those as in Canada in which calcite is usually present. In the former case the apatite crystals are characterized by the clear cut outlines and sharp edges observable in the microscopic specimens; in the latter the faces and edges of the crystals always exhibit a most extraordinary appearance of fusion, which formed the object for a very careful examination, of all material available in the University museum.

44. The peculiar waxy lustre of the crystal faces, the rounding of edges and coigns, the more or less complete corrosion of the crystals themselves were extremely striking peculiarities. In numerous cases where the crystals were very much corroded, particles of calcite filled the corroded parts. Where shallow depressions were observed on the crystal face, an examination of the calcite originally in contact revealed corresponding elevations which exactly fitted. This was most noticeable in a specimen of apatite in calcite collected by Dr. Coleman in Sebastopol. In a specimen of his from South Burgess, the action had continued to the greatest extreme. In this the apatite had been entirely removed, leaving a negative crystal. In this and every other case the surfaces of calcite which had been in juxtaposition, showed the same waxy lustre observed in the affected apatites.

45. In several specimens in the University museum the apatite crystals had been broken and recemented, the recemented parts being in slightly altered positions. These extreme cases of alteration such as

[29] C. R. 126 : 1532.

alluded to in the preceding paragraph, occur invariably in the presence of calcite, and apatite crystals found imbedded in other rocks show this peculiarity in a lower degree.

46. Other minerals occurring along with apatite in connection with calcite exhibit to a certain extent the same peculiarities. A specimen of black hornblende from Otty L. which I collected, had scattered inclusions of rounded apatite grains. In another specimen similar rounded grains of calcite were found in a crystal of augite. Finally a number of specimens in the University laboratory consisted of calcite in which were scattered small crystals of hornblende and augite which showed the same rounded edges already noted in the case of apatite.

47. Two other specimens showed characteristics which have a bearing upon this discussion. A specimen in the University museum consists of a hornblende pierced by interpenetrating apatite crystals. The large phlogopite crystal observed by the writer in the Lacy mine gives an indication of the very slow cooling of the magma.

48. These facts throw considerable light upon the order of events in the formation of the apatite deposits. Crystallized out of a magma cooling so slowly that a crystal of phlogopite of several tons weight could be produced as well as the enormous crystals of apatite of several hundredweight as in the specimen in the museum, the apatite crystallizing first could form inclusions of a size to be measured in inches. Subsequently an increase of heat, while the deposits were still under great pressure reduced the apatite when in contact with calcite, to a liquefiable mass. It is evident that this was not the result of heat alone as it only occurs in the presence of calcite.

VI.—EVIDENCE FROM ASSOCIATED MINERALS.

49. A characteristic of the occurrence of the Canadian apatites is the constant presence of certain associated minerals. Phlogopite, calcite, graphite, magnetite, anhydrite, and several others are found in varying quantities in every apatite deposit. This fact throws considerable light upon the origin of the apatite, more especially in the case of the four last mentioned, whose bearing on the problem will be discussed seriatim.

50. Calcite is the commonest "vein-stone" in all apatite deposits, and its presence is one of the distinctive peculiarities of the Canadian deposits. It is worth remembering that analogy would suggest an organic origin for all calcite. To be sure it is conceivable that the primordial ocean

may have been a solution of calcium chloride which was precipitated as carbonate by rain water highly charged with carbon dioxide, but such a theory can be deduced only by *a priori* reasoning incapable of support by facts. According to the uniformitarian theory all rocks were formed by processes similar to those now taking place. Now every deposit of limestone at present being formed is primarily or secondarily organic, and this is the case in practically all large unmetamorphosed masses of calcitic rock. In mineral veins it is true the calcite vein-stone may be considered to be due to the concentration of calcium carbonate from the country rock, but this has to do with small deposits only.

51. It has been pointed out at an earlier place that the colouring matter of certain of the apatites is due to some included organic compound, and the question occurred whether the similar colouring of the calcite were due to the same cause. A number of experiments were made with pinkish, flesh coloured and dull red specimens, such as are found so commonly with the apatite deposits. It was found that on heating, the characteristic organic odour was observed, and that when cooled the colour had gone. This would indicate a similarity not only in the appearance, but also of the very nature of the pigment in certain organically tinted apatites, and the associated calcite of a similar colour.

52. It has already been noted that the contact surfaces of the apatites and calcite show the same waxy lustre, and this and other facts already referred to seem to indicate that the fusion effects observable in the apatite are due to the action of calcite in a viscid or liquid state under the influence of combined heat and pressure. This being the case, traces of the dissolved apatite should be found in the calcite.

53. A number of sections of the calcite were made and examined microscopically for indications of apatite, but in no case were they met with. If the apatite has been eroded by the calcite it must have been thoroughly dissolved. In a number of cases the calcite was examined by qualitative analysis which revealed the presence of phosphoric acid. Finally several gravimetric analysis were made with a view of determining the proportion of phosphoric acid present. Two of these gave the following results:

	I	II
Weight of calcite	3.4164	3.1118
Weight of crucible and ash	6.1286	6.1282
Weight of crucible	6.1260	6.1260
Weight of ash	0.0022	0.0026
Weight of filter ash	0.0002	0.0002
Weight of magnes. phos	0.0020	0.0024
Percentage of phosphoric acid	0.221	0.191

From this it is evident that while the action was in progress the calcite was in a sufficiently liquid state to completely dissolve away parts of the apatite crystal.

54. Graphite is a mineral whose chemical composition most strongly suggests an organic origin. It is frequently found under conditions which point undeniably to this, as for instance where intrusive dykes cut across coal beds. This mineral is, according to Van Hise[30] never found in the Archean, its lowest horizon being the Algonkian which is in all probability a clastic series. It is interesting to note that in the amorphous nodular phosphates of North Wales of Cambro-silurian age, graphite occurs in sufficient quantities to colour the rocks.

55. Magnetite is a constant associate of apatite, often in very considerable amounts. In many places at the present time iron ores are in process of deposition, and the mode of formation can be readily traced. Water containing decaying vegetable matter, and in consequence strongly charged with humic acids, forms unstable soluble salts of iron, which are dissolved. These, on exposure to the air, form hydroxides which gradually change to limonite, and this we know becomes magnetite on metamorphism. According to Ehrenberg, the presence of diatoms has an equal part to play in the formation of iron ores. These microscopic plants have the power of concentrating the iron in water in their bodies which finally form deposits of great thickness. Thus either theory of the formation of the iron ores, leads us to the action of plant life.

56. Anhydrite is another associated mineral whose presence has considerable bearing on the problem. It does not occur in very large quantities, but that is to be expected from the great solubility of gypsum. Lagoon muds are exceptionally rich in phosphoric acid and also in sulphur. The latter becomes oxidized to sulphuric acid which attacks the surrounding limestones at the same time that the phosphoric acid does and calcium sulphate and phosphate are formed.[31] This will explain the presence of anhydrite with apatite, for as a rule phosphates would be laid down in lakes or lagoons, and the ordinary way of the deposition of gypsum is in land locked bays of considerable depth, which gradually increase in concentration.

57. Thus it is seen that four of the characteristic associated minerals which occur with apatite are those which under any other circumstances would be looked upon as of undoubted organic origin.

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[30] Penrose, p. 80.
[31] Dieulafait, Ann. de Ch. et de Phys. 6 series 5: 204—1885.

VII.—Conclusion.

58. Several facts which have a bearing upon the problem of the origin of the Canadian apatites have been referred to in the preceding pages. They may be briefly summarized as follows:

(1) Decaying organic matter has the power of absorbing phosphoric acid from water containing even a minute proportion in solution.

(2) Every known deposit of mineral phosphate except the true apatites can be traced directly or indirectly to an organic origin.[32]

(3) Phosphates of known organic origin will take up the fluorine from water containing even an infinitesmal proportion, and thus tend to produce the stable apatite-molecule.

(4) There are unmistakable evidences that this has actually been the case in earlier ages.

(5) The surrounding rocks do not contain phosphoric acid either as apatite or a molecular mixture.

(6) The Canadian apatites occur in deposits which are at least to a considerable extent bedded.

(7) In association with the apatites occur calcium sulphate, in the form of anhydrite, a substance which is of undoubted sedimentary origin, and also calcite, gypsum, and magnetite whose mode of origin is apparently organic.

(8) The colouring matter of the apatite as well as that of the adjacent calcite is an organic substance.

(9) The apatite crystals, and to a lesser degree other associated minerals have been subsequently corroded, the associated calcite shows indications of similar alterations, and contains dissolved portions of the apatite.

59. From these facts it seems justifiable to deduce certain conclusions as to the stages through which the Canadian apatite deposits have passed before assuming their present condition. These form the thesis which this dissertation endeavours to maintain. They are as follows:

(1) The Canadian apatites are the final product of original accumu-

[32] Falding—Eng. Min. Jour. '85.

lations of phosphatic organic material, which may have increased their percentage of phosphoric acid by condensation from sea water.

(2) The phosphates thus formed absorbed fluorine from the water in which they lay tending to form the stable apatite molecule. The fluorine was in certain cases molecularly replaced by chlorine, thus causing the various kinds of apatite. Subsequent metamorphosis finally gave the calcium fluo-phosphate the crystalline form of apatite.

(3) The peculiar corroded appearance of the apatite is due to the action of the associated calcite while in more or less fluid condition.

60. In conclusion, I wish to express my thanks to Professor A. P. Coleman, at whose suggestion this research was undertaken, and who has supplied me with much of the material used.

THE STELE OF OSMUNDA CINNAMOMEA.

By J. H. Faull, B.A., Ph.D.

The Seedling.

Hitherto the seedlings of three members only of the Osmundaceæ have been described, namely *Osmunda regalis* by Leclerc du Sablon (8), *Todea hymenophylloides* by Seward and Ford (12), and *Todea Frazeri* by Chandler (3). Leclerc du Sablon's description is very brief; he states that the course of development of the stem in *Osmunda regalis* is essentially the same as in other ferns. The base of the stem is occupied by a protostele, farther up a pith makes its appearance and simultaneously the cylinder of xylem is broken by gaps above the points of departure of the leaf-traces. He notes the lack of internal phloem and internal endodermis, but points out that a similar condition prevails in *Polpodium aureum*.

Seward and Ford state that their examination of the seedlings of *Todea hymenophylloides* proves that this species of Todea agrees in essentials with *Osmunda regalis*. The point of greatest interest in their account is the assertion that they could discover no trace of an endodermal layer in the medullary region of the seedling stele.

Chandler (3) in the course of his rather extensive paper on fern seedlings describes *Todea Fraseri*, the details of the development of which are like those of *Todea hymenophylloides*.

Reference was made by Faull (4) to some rather young plants of *Osmunda cinnamomea*, but their incompleteness, especially in regard to the youngest and the critical stages, forbade any detailed account. Quantities of seedlings in all stages, however, were found by the writer, in the neighbourhood of Stratford, Ontario, in the autumn of 1902, growing on hummocks in an open swampy tract of rich, but badly drained land, and the following description is based on these plants.

With regard to the primary root and the transition region between root and stem, nothing new presents itself with one noteworthy exception, a so-far unrecorded feature for any member of the family. A fungus in abundance occupies the cortical cells of the primary and first formed

secondary roots, the base of the stem, and of the bases of the lower leaves (Figs. 3 and 5). It is closely restricted to the cortex, not penetrating at any time even into the endodermis. The mycelium consists of rather coarse (5-7μ) filamentous, branched, infrequently-septated hyphæ; it forms loose elongated coils or bundles often in contact with the enlarged and apparently well-nourished nuclei of the host cells; here and there a hypha passes from one cell to another, and occasionally the ends of some of the hyphæ have the form of much swollen vesicles. So far as could be observed, the vigour of the ferns was in no way impaired by this association; in fact, the presence of the fungus was wholly unsuspected until microtome sections of the seedlings had been examined.

The details of the development of the stem are somewhat variable so that a generalized account will be given followed by a description of the sequence of events in several individual specimens.

A short distance above the transitional region between root and stem, at about the level of the foot and on the side of the stem opposite it, the first leaf trace comes away. Frequently a little farther up and at about right angles to the plane of the cotyledon the first root takes its origin. The earliest leaf-traces to the number of from five to eight alternate on the stem according to a $\frac{1}{2}$ system of phyllotaxy thus exhibiting a bilateral symmetry that seems to be characteristic of all fern seedlings. This is followed by a more or less regular $\frac{3}{8}$ system which may prevail until fifteen or twenty additional leaves have formed. The roots occur with a regularity almost equal to that of the leaves. The roots arise singly, one for each leaf, at about the level at which the leaf-trace separates from the cauline stele, and about 90° around the stem from the corresponding leaf. Thus if the points of origin of leaves and roots were plotted on a spiral there would be a regular alternation of the two. In *Osmunda cinnamomea* one root for each leaf is also characteristic of the adult plant, and not two as is the case for *O. regalis* and *O. claytoniana*. It is attached much nearer to the leaf-trace in the adult than in the seedling, often in part to its base.

The departure of the first few leaf-traces causes no other impression on the xylem of the cauline protostele than a temporary diminution of its tracheids (Fig. 1). But flattenings and bays above the points of separation of the leaf-traces may occur anywhere from the third to the eighth node (Fig. 2). Even an ephemeral pith may be formed by the xylem closing up the mouth of one of these bays (Fig. 3).

Following the restoration of the protostele with its central core of tracheids there is a repetition of the flattening of the xylem above the leaf-

traces, followed at subsequent nodes by broad or narrow bays of parenchyma, which may extend to the centre of the protostele. It nearly always happens that these bays are anticipated by nests of parenchyma appearing in the xylem below the level of the leaf-traces. Into the broader even of the earliest-formed bays, the phloem dips more or less. The bays just described are usually quickly re-filled with xylem, but eventually one deeper than any of the preceding is enclosed as the ends of the xylem surrounding the gap come together. This incipient stelar pith likewise often disappears, and may repeatedly appear and disappear before it is finally established as a permanent feature. Permanence is sometimes attained at the level of the twentieth node, sometimes higher up on the stem.

The permanent stelar pith at the base of the stem is narrow and comparatively few-celled. Soon after its establishment the overlapping of leaf-gaps may begin—a feature not infrequently observable at the level of the twentieth to the twenty-fifth node. From this time on, there is a slow increase in the size of the pith, and continuously an increase in the number of overlapping leaf-gaps. But the pith is yet relatively meagre and there are no more than two or three or four overlapping gaps when the internal endodermis first appears. It is to be pointed out that before, and even after the internal endodermis comes on the scene, indeed, even in the adult, leaf-traces may occasionally originate *cladosiphonically*, that is from the face of the cylinder of xylem without causing a complete break in its continuity. In such cases a pocket of parenchyma is found in the cylinder of xylem, which communicates above the leaf-trace with the parenchyma surrounding the xylem, but not with the pith. This phenomenon will be dealt with later on.

The first indication of the internal endodermis is a single tanniniferous cell marked by the radial "dots" peculiar to the endodermis. This is quite rapidly added to until there is a group of three or four or more, and finally with the increased numbers, they form a ring within which one and then an increasingly larger number of parenchyma cells appear. But the endodermal pocket may almost or quite die out and then re-appear before a constant internal endodermis is fully established. During the progression of these events several leaf-traces take their departure from the stem, leaving gaps in the xylem, through which I found no communication of internal and external endodermes. One fact, however, may not be without significance in this connection, namely, that rows of tannin-bearing endodermal cells frequently radiate out from the internal endodermis into the large leaf-gaps, and similar groups may temporarily occur just centrad of the middle line of the departing leaf-traces. In fact,

the internal endodermis shows a constant tendency to dip outward into the leaf-gaps and at times in the adult so far as to reach the external endodermis (Fig. 11).

Another striking phenomenon is the eccentric position of the internal endodermis in its initial stages. Not only is it eccentric, but it originates at the inner entrance to a gap that marks a separating leaf-trace (Fig. 4). Such a position and mode of origin of endodermal pockets are so common in filicinean steles with pith admittedly of extrastelar homologies that their occurrence in Osmunda is of more than passing interest.

The first-formed leaf-traces are collateral, the rest are concentric. The "quergestreckte Zellen" of Zenetti or tangentially elongated peripheral phloem cells of the stem are not present in the seedling. They begin to appear later, that is when there is a more frequent overlapping of the leaf-gaps than maintains in the seedling. The phloem on the inner face of the leaf-trace is throughout in continuity with the phloem that surrounds the xylem of the stem. It has been held by Tansley that this argues against the view that the primitive siphonostele was amphiphloic, but this seems to be making a far-fetched application of the textural continuity of like tissues. This view was bound up with another for which I can also see no adequate justification, namely, that a reduction of the cauline stele would mean a reduction of the leaf-trace.

The stipule-like wings on the petioles are very striking in the leaves of the seedling; sometimes they are so broad as to reach more than half way around the stock (Fig. 6).

SPECIFIC EXAMPLES:

A.—A little above the foot, and opposite to it the cotyledonary trace separates from the cauline stele, and almost at the same time, and 90° around from it the first root. The first four leaves are arranged bilaterally on the stem. The same is also true of the roots except that the fourth root accompanies the fifth leaf-trace. With the fifth trace is initiated the ⅜ arrangement. Up to the sixth leaf-trace the stele is not affected by the foliar traces, but preliminary to the segmentation of the sixth leaf-trace, a pocket of three parenchyma cells appears. Above, there is a wide bay occupied by from three to five cells surrounded by a curved line of tracheids. The ends of the crescent close around a pith of eight cells. This pith almost immediately disappears, and is not re-formed at the next node.

B.—Just above the junction of the first leaf-trace there are four tracheids in the cauline stele and three in the foliar. This number increases, but is very fluctuating, at the fifth node there being only nine in the one and three in the other. The first four leaf-traces answer to the ½ arrangement, the later ones to the ⅜. The first root arises near the fourth node and the xylem of the stele remains wholly undisturbed in shape up to the seventh node except for a slight flattening at the sixth.

C.—The phyllotaxy of the first six leaf-traces is approximately symbolized by ½ and the roots which are in a plane at right angles to that passing through the leaf bases are similarly arranged. The ⅜ arrangement begins with the seventh leaf. The first disturbance in the stele occurs at the seventh node, where there is a flattening above the node. An eccentric parenchyma pocket of three or four cells is formed just below the ninth node, but the ninth leaf-trace is cut off by a band of parenchyma as in the tenth, and in neither case is there a gap nor any indication of a pith.

D.—The arrangement of the first five leaves is of the ½ type; with the sixth begins the ⅜. The first root comes off at the third node, and the second below the sixth. There is no change in the shape of the stele up to the eighth node.

E.—The first seven leaves are arranged in two lines on opposite sides of the stem, the ⅜ arrangement begins with the eighth leaf. The roots occur without a break up as far as the apex of the stem, that is through seventeen nodes, a root for each leaf, and in a plane about at right angles to the radius of the stem that cuts through the corresponding leaf-trace. The xylem of the cauline stele at the first node consists of thirteen or fourteen tracheids, the leaf-trace of six or seven; at the third node the former consists of about twenty-five tracheids and the latter of ten. There is a flattening of the xylem of the stem at the third, fourth, and fifth nodes; at the sixth node there is a laterally-placed pocket of two or three parenchyma cells, that opens out as a bay or depression in the xylem, just above the connection of the leaf-trace. At the seventh node there is again a pocket of three or four cells, and a corresponding V-shaped depression just above the point of origin of the foliar strand, and into which the phloem tends to dip. The xylem soon rounds up again, but at the eighth node there is a repetition of the phenomena described for the last two, except that when the gap closes up, a few parenchyma cells are included. A narrow pith of four or five cells now persists up through the tenth node, with a gap corresponding to each leaf-trace. The phloem is always most abundant opposite these gaps. At the eleventh node there is

neither pith nor gap, but at the next node there is a repetition of the events of the eighth. Above the twelfth there is a shallow, then a narrow gap, only a cell wide, reaching in to the heart of the xylem, that is about four cells deep. A pith of three or four cells is again enclosed. The leaf-traces are now concentric, but as yet there is apparently only meta-phloem on the ventral side. Above the thirteenth node, the narrow pith widens to two or three cells in breadth, and the gap formed overlaps that originating at the fourteenth node. Before the fifteenth node is reached, however, all gaps are closed, and there is a narrow pith of two or three cells in width and consisting of twelve cells in all. The gaps corresponding to the fifteenth and sixteenth nodes overlap. At the seventeenth node a pocket of parenchyma is formed as a diverticulum from the narrow pith, which soon opens to the outside as a gap of the seventeenth leaf-trace.

This seedling may be considered as the most nearly typical of all in regard to the sequence of events that take place in the course of its development.

F.—The base of the stem was lacking, and presumably about ten leaf-traces were missing. The roots occur with considerable regularity, but at the fifteenth node there was none. Above the eleventh node there was a deep narrow gap, and farther on a narrow pith. A separate pocket of parenchyma cells forms at the next node, but there is no leaf-gap above, and almost simultaneously the stele becomes a solid bulky mass of tracheids, round in section. In preparation for the next leaf-trace there is again a parenchyma pocket, but the gap above the thirteenth node is shallow and there is no pith. Above the fourteenth node a deep narrow gap appears, reaching to the centre of the core of xylem, and the next gap opens before this closes. The pith is about one cell in width. A pocket of parenchyma now forms, corresponding to the sixteenth leaf. This pocket opens out into the gap above the sixteenth node and connects at the same time with the already existing narrow pith. There is an overlapping of the last two gaps. The phenomena of the seventeenth node are nearly identical with those of the preceding. But above the seventeenth node there is a broad shallow gap which soon fills up with tracheids and the pith disappears. Once more there is a "solid" stele. At the eighteenth node there is a transitory pocket of parenchyma, but no gap or pith above. At the next node there is another pocket and a pith of four or five cells. These join, and above the node there is a deep narrow bay. The gaps of the nineteenth and twentieth internodes overlap. Above the twentieth leaf-trace there is a fairly deep bay in the xylem, four or five cells wide, and into which the external phloem clearly dips. A pocket of parenchyma

foretells the twenty-first trace, but it does not connect with the pith, and above the node is a very short-lived gap. Once more the pith dies out. But a pocket comes into existence at the succeeding node, and by the time the twenty-third node is reached there is once more a long narrow pith. All this time the xylem has been slowly increasing in amount and has become quite bulky.

G.—The base of this seedling was also lacking, and presumably the lowest node remaining was about the twenty-fifth or thirtieth. By this time there was a small permanent "pith" and there were two overlapping leaf-gaps. The roots occurred with regularity about 90° around from the corresponding leaf-traces, and not near the latter as in the adult stems. Ten leaf-traces were passed before the first endodermal cell appeared at the inner entrance to the last leaf-gap. The course of the development of the endodermis calls for no further description than that already given, other than to re-iterate the fact that as it expands it shifts its position somewhat, and shows a tendency to send diverticula out into the newly formed medullary rays.

THE ADULT.

(a) Branching.

The stem of *Osmunda cinnamomea* may branch occasionally, sometimes once, sometimes not at all. There is no reason to suppose that it may not branch more than once as do its two native sister species, but it has never been my fortune to find such a case. The branching has been described as "dichotomous," but this implies a phenomenon of the existence of which in this family we have absolutely no proof. Indeed, Mettenius (9) and Sadebeck (11) hold that dichotomy does not occur in the Filicineæ, and that here, as in similar cases throughout the group the branching is of the lateral type.

One of the apparently peculiar features in connection with the branching of *Osmunda cinnamomea* is the frequent accompaniment of ramular gaps. These are of varying degrees of openness; in some instances they gape so widely that there is a broad connection between the pith and the cortex, in other instances, there is no indication of a gap, even in the xylem, and between these extremes there are numberless intermediate grades. That these gradations or even the phenomenon of branching itself have any phylogenetic meaning as far as the nature of the stele is concerned, remains to be proved.

(b) Leaf-gaps and cladosiphony.

Occasionally leaf-gaps occur in *Osmunda cinnamomea* through which internal and external endodermes connect and even pith and cortex (Fig. 11). But the typical leaf-gap is occupied largely by parenchyma which is not penetrated by the endodermis, but into which a cone (as it appears in transverse sections) of the external phloem projects more or less deeply, and outwards into which the internal endodermis often tends to run (Fig. 11). In the typical leaf-gap, too, a blind pocket extends from the inner end of the ray down into the xylem, or—to explain in another way—on examining an ascending series of transverse sections of the stem, one finds nests of parenchyma making their appearance in the strands of xylem, which on being traced upwards are found to be continuous with the parenchyma of the medullary rays. It is worthy of observation that these *nodal pockets*, as they may be called, are just centrad of and in direct contact with the protoxylem elements of the strands in every case. Similar pockets are quite commonly absent in the early medullated stages of the seedling of *Osmunda cinnamomea*, and now and then in the adult, but they constitute such a characteristic feature of the Osmundaceæ, living and fossil, (cp. with the nodal pockets *Gleichenia pectinata*, and the Gleicheniaceæ) that a study of the phenomena connected with them may prove helpful in clearing up some phylogenetic tangles.

The first indication of a parenchyma pocket in the stele of *Osmunda cinnamomea* is represented in Fig. 15a by three cells in the xylem. These are continuous with the cells occupying the bay in 15b, and the pith in 15c. These sections were taken in the neighbourhood of the sixth node of specimen A, and as has been already stated the stele returns to the protostelic type before the next node is reached. In Fig. 14 (from specimen E) another pocket of three cells is represented—in this case it is the end of a "bay" which has been closed off by one or two tracheids as is shown. This stele likewise resumes the protostelic type farther up the stem, but neither here nor in the case represented by Fig. 15 can the pocket be affirmed to be homologous with the nodal pockets of the adult. But the remaining instances cited may reasonably be regarded as such.

Fig. 16 represents a section higher up in specimen E, and as is evident there is a narrow (though not permanent) pith. A leaf-trace is just separating, its upper edge has already broken away, and the position of the lower edge is marked by a small x in one of the tracheids. The "pocket" at this level is wider than the pith and has been continuous with the latter from the first. In the same figure, there may readily be detected two contiguous parenchyma cells, one with a nucleus, in the bulkiest part of the xylem—these constitute the bottom of the suc-

ceeding nodal pocket. A short distance up it opens into the pith and becomes as large as the lower one. It happens sometimes, however, that the tracheids so multiply that such a connection is not effected and even the pith may be obliterated.

Fig. 17 is a drawing of a young stele that has acquired a permanent pith, though even here the tendency of the xylem to encroach on the pith is evident. In the lower portion of the figure a leaf-trace is represented as about to take its departure. The pith in this region is broader than elsewhere, but it is continuous downward into a pocket like the one to be next pointed out. It will be noticed that this leaf-trace contains a considerable segment of the cylinder of xylem, and that the foliar gap or medullary ray is comparatively wide. At the upper left of the pith is represented the next pocket, a narrow bay of from four to six parenchyma cells and continuous with the pith.

At many other nodes, just as in Fig. 16, the pocket is not continuous at first with the "pith," but opens out into it later on. Indeed this becomes, even before the seedling stage is passed, by far the most usual mode of origin. Thus in Fig. 4 a rather large pocket is shown at the upper left—a pocket that farther up connects with the tissues enclosed by the xylem. A pocket in an adult stem is figured in Fig. 11 in the lowermost entire bundle. The one tracheid centrad of it shortly disappears so that it joins with the parenchyma just within.

The nodal pocket is associated with some interesting variations that throw light on its homologies. If the pocket be large as in Fig. 9, an isolated group of endodermal cells may make their appearance in it, which, when the pocket opens inward, in most cases, perhaps in all (I regret not being able to make a more definite statement on this point) connects with the internal endodermis. Occasionally the nodal pocket does not open into the tissues surrounded by the xylem, just as at the left in Fig. 7, and in Fig. 8. If Fig. 7 be studied, it will be seen that the connection may at times be made very late, that is some distance above the level at which the leaf-trace separates. Thus in the upper middle a bay or medullary ray (into which the nodal pocket has opened) almost penetrates the xylem, and in some instances actually does so farther up the stem, just as has happened in the lower middle of the same figure. In conclusion the phenomenon of cladosiphony, whether in the seedling or the adult, is to be looked for in stems or portions of stems where the xylem is comparatively thick, and where it apparently shows a centripetal proliferation.

Such are the observations on the nodal pockets of *Osmunda cinnamomea*. As to their interpretation two conclusions are suggested—that they are homologous with the tissues enclosed by the xylem, portions (usually of parenchyma only) that are enclosed by the xylem for a greater or a less distance; and that they owe their existence to an evolutionary tendency on the part of the xylem to increase in the direction of the pith. If such be the case, the nodal pockets are to be regarded as indications of "cladosiphony"—not primitive, but a cladosiphony secondarily produced.

A perfect condition of cladosiphony may rarely be observed in normal stems, the xylem in such cases remaining unbroken on the medullary side. This phenomenon is of rarer occurrence than might appear from an examination of a single or a few serial transverse sections, for on account of the obliquity and tenuity of the ray it is demonstrable only in complete series. The same explanation may be given as for the pockets, complete cladosiphony resulting from an entire closure of the inner end of the medullary ray.

But the most pronounced instances of "cladosiphony" were found in plants that had been subjected for some time to adverse conditions. In such plants there is often a great diminution in the size of the stele, and it not infrequently happens that while there may be deep pockets of parenchyma opening outward, not a gap is formed for several nodes (Figs. 7, 8, 10).

These plants were collected in the neighborhood of Toronto and were quite readily detected by the smaller size and number of their leaves. They were not seedlings, for each one was carefully traced back from the crown, and was found to have formerly possessed a stem of normal adult robustness. Just what the adverse conditions were was not determined.

The sequence of events in the stele of one of these proved to be of peculiar interest, because of the discovery of an internal phloem, and hence will be given in some detail.

The stele gradually diminished in diameter and the medullary rays narrowed. Finally the xylem remained continuous on the medullary side; the cylinder of xylem was relatively very thick, and the parencyhma pockets and external bays above the leaf traces well developed. The pith was reduced in volume. The leaf-gaps several nodes up again formed. This was followed by closure and an extensive sclerification of the pith. By degrees the outer surface of the xylem became smoother, and the thickness of the wall of the cylinder to diminish. Very soon isolated

sieve-tubes appeared in the thickening band of parenchyma between the internal endodermis and the xylem, to be succeeded by a continuous layer of phloem two or three cells thick, separated from the internal endodermis by parenchyma and likewise from the wood. Preceding this strengthening of the internal phloem there was a shrinking of the now parenchymatous pith and a thinning of the wall of the cylinder of xylem. The leaf-traces during the later stages were reduced and their separation made little impression on the xylem. A short distance above the establishment of the internal phloem, a considerably larger leaf-trace took its origin from one end of an elliptical (in transverse section) stele, accompanied by a thickening of the xylem and internal parenchyma at that end, the formation of a few isolated tracheids in this internal lining of parenchyma and a very narrow gap. The internal phloem extended out somewhat in the direction of this gap, but did not reach into it (Fig. 10). The stele rapidly closed up, subsequent leaf-traces originated cladosiphonically and the pith and internal endodermis disappeared, the xylem now surrounding a layer of parenchyma and a considerable mass of phloem in the centre, which also soon died out.

(c) Accessory strands.

Kidston and Gwynne-Vaughan call attention to bundles lying just within the cylinder of xylem on one side of the pith in the section of *Osmundites Skidegatensis* examined by them. Strands of an apparently similar nature sometimes occur in *Osmunda cinnamomea* varying all the way from single tracheids to groups of considerable size. The ones represented in Fig. 12 were taken from a region of branching and are exceptionally prominent. They are nothing more than portions of the cylinder of xylem shut off from the main part for a longer or a shorter distance by parenchyma.

It is interesting to note in this connection that isolated tracheids laterally situated in the pith (centrad of the internal endodermis) have been observed several times. Such tracheids are surrounded by a ring of endodermal cells, and have obviously been "pinched off" from the stele.

CONCLUSIONS.

Regarding the phylogeny of the Osmundaceæ, there is a wide diversity of opinions,—a diversity due to fundamentally different conceptions of the evolutionary history of the stele. Van Tieghem (14) and subsequently Zenetti (15), basing their theory on the structure of *Osmunda regalis*, held that the Osmundaceous siphonostele was derived from a protostele

by a simple process of expansion. The pith was thus regarded as stelar, in which respect the family stood as an exception among the Filicineæ. Seward and Ford (12), Tansley (13), Kidston and Gwynne-Vaughan (7), and Bower (2) have recently adopted the same view, and have stretched it to cover the dictyostele of *Osmundites Skidegatensis*, the siphonostele of *Osmunda cinnamomea* with its internal endodermis and locally distributed internal phloem (4, 6), and the siphonostele of *Todea hymenophylloides* with its more or less distinctly marked internal endodermis (12).

They believe that the more complex steles of these forms have been derived from a medullated stele such as that of *Osmunda regalis* by a differentiation of the pith, and hence that the occurrences of internal endodermis and internal phloem are indications of an upward evolutionary tendency towards the amphiphloic siphonostele—an attainment most nearly realized so far in Penhallow's *Osmundites Skidegatensis*.

An opposite view, in harmony with Jeffrey's stelar theory, was elaborated prior to this by Faull. It was contended that the history of the stele of the *Osmundaceæ* has not been exceptional as suggested by Van Tieghem, and, therefore, the stage following the protostelic was the amphiphloic siphonostelic, which was brought about by an "intrusion" of the phloem, endodermis, and cortex into the protostele. It was further maintained that the simpler steles of living forms represent various degrees of modification from the amphiphloic siphonostele. Accordingly the siphonostele of *Osmundites Skidegatensis* is believed to be the most primitive known in the Osmundaceæ, and that of *Osmunda regalis* one of the most specialized.

In attempting to work out the phylogeny of this family, investigators have pursued three lines of inquiry, namely ontogeny, comparative anatomy, and palæobotany. There are indications that a fourth, experimental morphology, is important, but it has not yet been exploited.

ONTOGENY.

Kidston and Gwynne-Vaughan (p. 774) sum up the contentions of the anatomists who hold that the Osmundaceæ represent an ascending series in the following words: "The theory of reduction has met with strong opposition from subsequent writers, Boodle, Seward and Ford, and Chandler, who base their objection chiefly upon the confirmatory evidence in the stem of the young plant. We entirely agree with their criticisms, and prefer to regard the Osmundaceous type of vascular system as derived directly from a primitive stele possessing a true pith, surrounded by a stout and perfectly continuous ring of xylem. The leaf-traces departed

from this stele in a protostelic manner, that is without leaving any depression or gap into which the external tissues could subside. Bower (p. 538) likewise affirms "that a good basis for an opinion opposed to a theory of reduction is to be found in the ontogeny of the living plants, for in the seedlings there is at first a protostele without internal complications, which expands later, and becomes medullated; but at first the passing out of a leaf-trace does not necessarily interrupt the continuity of the xylem ring; leaf-gaps are not found till later."

Professor Bower's contention is met in full, and Kidston and Gwynne-Vaughan's in part at least by the ontogeny of *Osmunda cinnamomea*. Incidental to the departure of the leaf-traces there are flattenings and indentations of the xylem, parenchyma pockets, gaps, and a pith formed by the closing of a gap. The internal endodermis even originates as an eccentrically situated pocket at the inner entrance to a medullary ray, just where a leaf-trace is being given off, and it continually tends to connect with the external endodermis through the leaf-gaps. Internal phloem and wide-open leaf-gaps through which cortex and pith communicate were not found, however, in my material. Their absence may be indicative of reduction expressed in the seedling stage. The fluctuations in the course of development and the consequently long-drawn-out juvenile stage are matters of interest, the explanation of which is much to be desired.

COMPARATIVE ANATOMY.

(a) The homologies of the pith.

At the conclusion of his studies on the seedlings of Leptosporangiate Ferns, Chandler expressed the opinion that the pith of *Osmunda cinnamomea* was of extrastelar homologies and in accordance with this view fairly accurately forecast the description of the seedling as given in this paper. The features of the adult stem that favour this view are (1) the textural continuity through *branch-gaps* of like tissues, namely, external endodermis with internal endodermis, parenchymatous cortex with parenchymatous pith, and sclerenchymatous cortex with sclerenchymatous pith, (2) the same phenomenon in connection with the *leaf-gaps* of *Osmundites Skidegatensis*, (3) the occasional continuity of external endodermis and internal endodermis, cortex and pith through the leaf-gaps of *Osmunda cinnamomea*, (4) isolated tracheids in the pith are surrounded by a ring of endodermal cells. These are essentially the same criteria as those applied to ferns whose piths are admittedly extrastelar.

Granted that the pith of *Osmunda cinnamomea* is extrastelar, the similarity of the stelar anatomy throughout this family naturally leads

to a similar conclusion with regard to the bulky piths of other species. Seward and Ford's interesting discovery of a sporadically marked internal endodermis in *Todea hymenophylloides* provides the necessary bridge if one be required.

(b) Internal phloem.

The presence of internal phloem in *Osmunda cinnamomea* and *Osmundites Skidegatensis* has been difficult of explanation on the upgrade theory. Tansley does not attempt it. Kidston and Gwynne-Vaughan suggest that there has been a "subsidence" of phloem through branch-gaps as in the Lycopsida. Support for this suggestion has been drawn from the fact of localization of internal phloem in the neighbourhood of forking in *Osmunda cinnamomea*. Investigations prove in opposition to this, that branching is not a seedling character. Further, the external phloem tends to dip into the bays and the leaf-gaps of the seedling, and internal phloem has been discovered in a portion of the stem of *Osmunda cinnamomea* far removed from any region of branching. Indeed, the facts connected with the occurrence of internal phloem in the Osmundaceæ most readily harmonize with the theory that it originated in this group as in the rest of the Pteropsida, and then suffered degeneration to a greater or a less extent. According to this view *Osmunda cinnamomea* stands as the bridge between *Osmundites Skidegatensis* and such forms as *Osmunda regalis*.

(c) Internal endodermis.

On the upgrade theory the internal endodermis has been even more difficult of explanation than the internal phloem. The Gordian knot may be cut by denying that it is homologous with the external endodermis, but this would constitute it as an exception among the Pteropsida which is scarcely probable. Kidston and Gwynne-Vaughan recognize this difficulty, and suggest, though hesitatingly, that the external endodermis too, may have subsided through branch gaps. But it is peculiar neither in form nor behaviour and is most readily understood by being considered as homologous with the external endodermis, and as having originally entered the stele in the manner characteristic of other ferns.

(d) Nodal pockets.

The occurrence throughout the Osmundaceæ of pockets of parenchyma extending down into the xylem from the inner ends of the medullary rays is a matter of considerable interest, because there is reason to believe that a knowledge of their origin would shed considerable light on the course of evolution of the stele in this family, and because of the possibility

that they afford a point of contact with the Gleicheniaceæ. With the latter we shall not deal in this connection. As to the former, a study of many stems of *Osmunda cinnamomea*, both young and mature, has led to the conclusion that the tissues composing these pockets are homologous with the tissues surrounded by the xylem, or to be more specific they are the lower and inner ends of the slanting medullary rays that have been closed in as the result of a centripetal proliferation of the xylem. The fact that an endodermis, apparently a portion or extension of the internal endodermis, is sometimes found in these pockets, and that often in the seedling and occasionally in the adult the pocket is not closed in on the axial side, but is a groove or bay, the lower extension of the medullary ray, lends colour to this view. Moreover, that there is a tendency for the cylinder of xylem to thicken in the direction of the pith is borne out by the behaviour of the seedling stele, by the circumstance that individual tracheids and even bundles are frequently found encroaching on the pith, and by the fact that sometimes the internal opening to a medullary ray is partially or wholly closed. If this view be correct, then the nodal pockets are to be regarded as strong proofs of an evolution that tends *towards* "cladosiphony."

Palæobotany.

It goes without saying that the strata hold the phylogenetic secret. Great interest has therefore attached to Penhallow's account of *Osmundites Skidegatensis*, and Kidston and Gwynne-Vaughan's description of a series of fossils regarded as Osmundaceous. Bower has hailed arguments based on this recently adduced stratigraphical evidence as the most cogent yet advanced in favour of the upgrade theory. The readings from the strata are as follows (the quotations are from Bower's lucid summary p. 539).—

Grammatopteris from the Permian of Autun—"with a solid homogeneous protostele."

Chelepteris Zaleskii from the Permian of Russia, "showing a protostelic state, but with the central region of the xylem differentiated from the peripheral."

Chelepteris gracilis from the upper Permian of Russia, and *Osmundites Dunlopi* from the Jurassic of New Zealand, "with a continuous ring of xylem surrounding a central pith."

Osmundites Gibbeana from the Jurassic and *Osmundites Chemnitziensis* from the Tertiary quartz of Hungary with "an interrupted xylem ring that surrounds pith only," and *Osmundites Skidegatensis* from the Cretaceous which "shows internal phloem" and pith.

Obviously the protostelic fossils do not enter into the question. The siphonostelic forms later than the Cretaceous *Osmundites Skidegatensis* may also be passed over, for, to say the least, they do not lend strength to the arguments of Kidston and Gwynne-Vaughan, and Bower, that is, if their standards of interpretation of phylogenetic stages be rigidly extended to stratigraphical sequences. This leaves for consideration *Osmundites Dunlopi, Osmundites Gibbeana,* and *Chelepteris gracilis.*

The sole material of *Osmundites Dunlopi* is a single specimen of a portion of the stem three cms. long, "that had suffered a certain amount of decay and attrition before it finally became embedded in the rock." "Most of the leaf-traces if not all, depart without in any way interrupting the continuity of the xylem ring so that the medullary rays characteristic of the Osmundaceous stele in general are almost completely absent." What the xylem surrounded we do not know, for there is in this region "no trace of cell-structure." Scale leaves were found, which were believed to be due initially to certain adverse external conditions.

Chelepteris gracilis was studied from a specimen in a fair state of preservation, but lacking the extreme periphery of the stem, and from which "the central tissues have unfortunately disappeared." Moreover there seems to be some uncertainty as to the relationship borne by Chelepteris to the Osmundaceæ.

Osmundites Gibbeana is also based on a single specimen of a part of the stem about two cms. long. "The inner cortex and peripheral tissues of the stele were greatly decayed before fossilization;" there were medullary rays, but the tissue that composed them "has entirely disappeared." Presumably the same fate befell the tissues within the xylem.

Interesting as are these fossils, the soft tissues were not preserved, so that it is impossible to say what the xylem enclosed. Nor do they throw a ray of light on the origin of the pith—the crucial point, for without any question as to affinities, Grammatopteris, etc., might very well be regarded in the Osmundaceæ as is Lygodium in the Schizæaceæ, and the others, marked as they are by no medullary rays or very narrow ones, as reduced forms. In fact *Osmundites Dunlopi* possessed scale leaves, and was admittedly reduced, and the critical features (absence of medullary rays, or very narrow ones) of *Osmundites Dunlopi, O. Gibbeana,* and *Chelepteris gracilis* were just such as may be induced in *Osmunda cinnamomea* by subjecting it to adverse conditions.

It is significant that the Osmundaceæ can be traced back so far, and Kidston and Gwynne-Vaughan have made an important contribution

to botanical science in demonstrating the existence of the Osmundaceous type at such an early period. But it is extremely doubtful if their palæobotanical studies have as yet indicated in any way the course of evolution of the siphonostele from the protostele in the Osmundaceæ. Indeed, a very obvious conclusion to be drawn from their account would seem to be that even the Permian and Mesozoic siphonostelic members of this family, so far as they are known, possessed essentially the same specialized features that are characteristic of modern forms.

The facts in hand are believed to substantiate the hypothesis that the ancestral Osmundaceæ possessed a typical filicinean amphiphloic siphonostele. As an adaptation to the conditions of the habitat, the outer cortex became thickly sclerified, and as a co-relation, the central pith. As a further adaptation, there may have been a thickening pithwards of the wall of the cylinder of xylem, made necessary by the needs of fronds that had suffered insufficient reduction or none at all. This might have involved the formation of pockets in the wall and the narrowing of leaf-gaps, with eventually the loss of the connections between internal and external phloems, and endodermis. The next step in reduction was the loss of internal phloem and then of internal endodermis. It is possible to conceive that in some cases, either before or after this stage, the medullary rays and even the parenchyma pockets may have been completely obliterated. The whole gamut of reductions may have been run through in any geological age in any genus. The living genera are the offshoots of more or less reduced ancestors. Their seedlings do not repeat every phylogenetic stage, and exposed as they are to much the same environment as the adult, exhibit the same type of adaptation.

SUMMARY.

1. The cortical cells at the base of the seedlings of *Osmunda cinnamomea* examined were occupied by a fungus.

2. Individual plants vary considerably among themselves in regard to the details of their development. But in no instance is the transition from the protostele to the siphonostele effected by a simple expansion as has been claimed to be characteristic of the Osmundaceæ. There are bays or gaps in the xylem (often anticipated below the nodes by parenchyma pockets) in the neighbourhood of the nodes, and eventually the edges of the xylem close around the upper end of one of these gaps, the parenchyma thus enclosed constituting a "stelar" pith. The internal endodermis and "extrastelar" pith arise as an eccentrically situated pocket at the inner entrance to a leaf-gap. They do connect with the

external endodermis and cortex through leaf-gaps, but rarely, and so far instances have been observed in adult stems only. From their first appearance, however, they very commonly extend outwards into the leaf-gaps.

3. Branching is not a seedling character.

4. Internal phloem has been found in unbranched adult plants. This fact, and the absence of branching in the seedling are believed to indicate that there are no adequate grounds for regarding internal phloem and internal endodermis in the Osmundaceæ as having "intruded" through branch-gaps.

5. The parenchyma pockets extending down from the medullary rays into the xylem are sometimes occupied by an isolated portion, as viewed in transverse sections, of the internal endodermis. Often in the seedling and occasionally in the adult they are represented merely by grooves on the inner face of the cylinder of xylem. The origin of these pockets may be accounted for by the tendency of the xylem to encroach on the axial tissues, thus closing around the lower ends of the oblique medullary rays. This tendency is seen in the occasional closure of the inner entrance to the medullary ray, and in the existence of larger or smaller isolated strands of xylem on the pith side. Tracheids may even occur in the pith, in which case they are surrounded by a ring of endodermal cells. Thus the nodal pockets of the Osmundaceæ may furnish important evidence of an evolutionary trend in this family *towards* cladosiphony.

The "cladosiphony" of *Osmundites Dunlopi*, etc., is not infrequently paralleled in plants of *Osmunda cinnamomea* that have been growing under adverse conditions.

6. The stele of the existing Osmundaceæ is regarded as a reduced amphiphloic siphonostele, and hence the homologies of the pith, and the origin of the siphonostele as concordant with the stelar theory of Jeffrey in its application to the Filicineæ.

University of Toronto, June, 1909.

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ILLUSTRATIONS.

1. Transverse section of stem of seedling of *Osmunda cinnamomea* above the third node.

2. Transverse section of stem above the fifth node showing depression in stele.

3. Transverse section of stem above the eighth node, showing closure of gap to form a "stelar" pith. The cylinder of xylem is unusually thin. At the lower right the associated fungus may be seen in the cortex.

4. A transverse section of the stem of a seedling showing the first appearance of the internal endodermis. It is the dark spot in the pith at the entrance to the last formed leaf-trace.

5. A longitudinal section of the cortex of a seedling showing a line of cells occupied by the fungus. The surrounding cells are heavily-laden with starch.

6 A section of a seedling showing the winged petioles.

7. A section of an adult stem that has become much reduced in size. Most of the medullary rays are closed on the pith side.

8. An enlarged view of the stele of a section a short distance above the one represented in Figure 7.

9. A part of the stele abutting on the pith. The long row of dark cells is a portion of the internal endodermis. An isolated group of endodermal cells occupies a parenchyma pocket.

10. A much reduced adult stem in which an internal phloem is well-developed

11. A normal adult stem showing a leaf-gap through which internal and external endodermes, pith and cortex communicate. In the cortex is the corresponding leaf-trace, and to the right a root-trace.

12. A portion of the stele in the neighbourhood of a fork showing internal phloem and isolated strands of xylem.

13. Transverse section of the stele and endodermis at the second node.

14. Transverse section of the stele and a leaf-trace just above twelfth node.

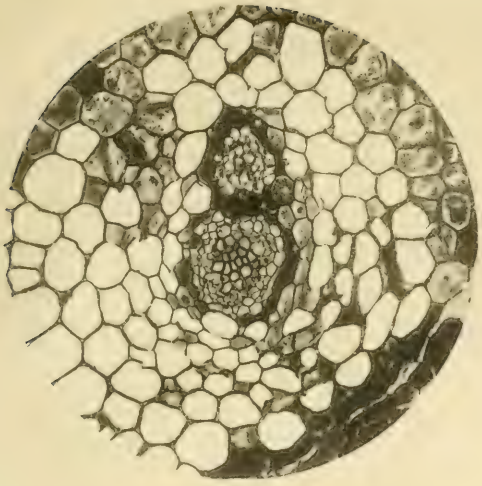
15. Three sections in the neighbourhood of the eighth node, (a) below the node, (b) at the node, (c) above the node. (*p.* pericycle.)

16. Transverse section of stele and endodermis at about the sixteenth node.

17. Transverse section of stem several nodes higher up.

18. A segment of the cortex of a seedling, some of the cells of which are occupied by a fungus. The rounded dark bodies shown in several of the cells are nuclei. Three of the infected cells contain irregular masses of dark-staining substance intermixed with closely-packed hyphæ.

19. A segment of a section of the stele not far from the one represented in Fig. 10. (*e.e.*, external endodermis ; *ph.*, external phloem ; *i. p.h.*, internal phloem ; *i.e.*, internal endodermis.)



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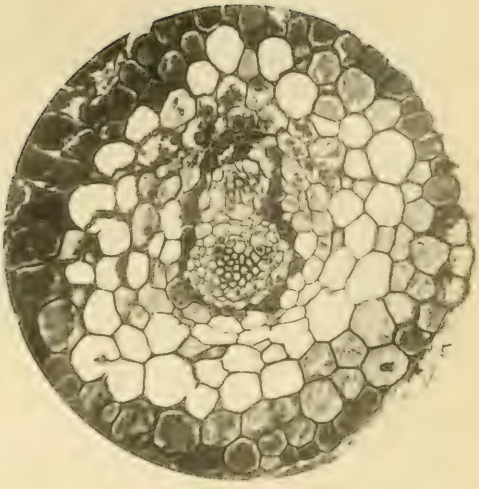

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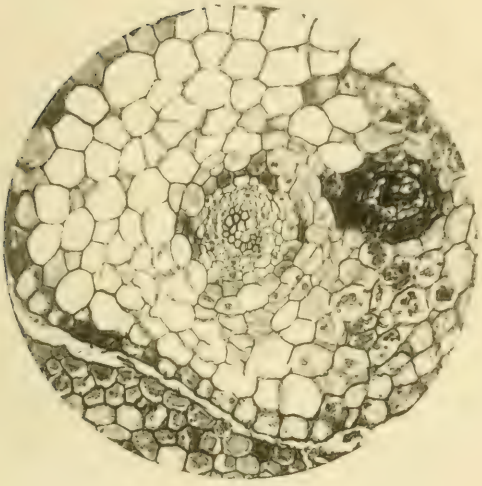

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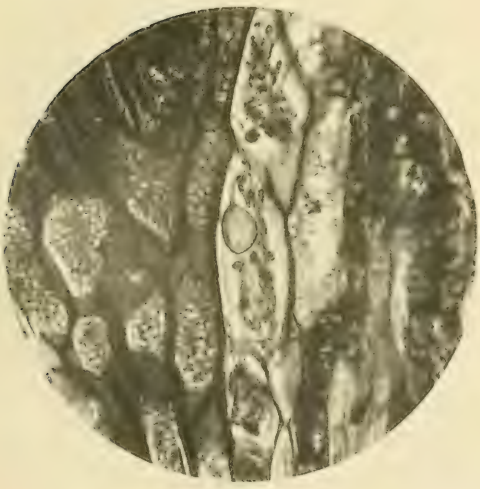

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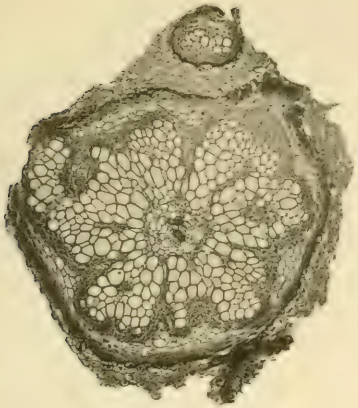

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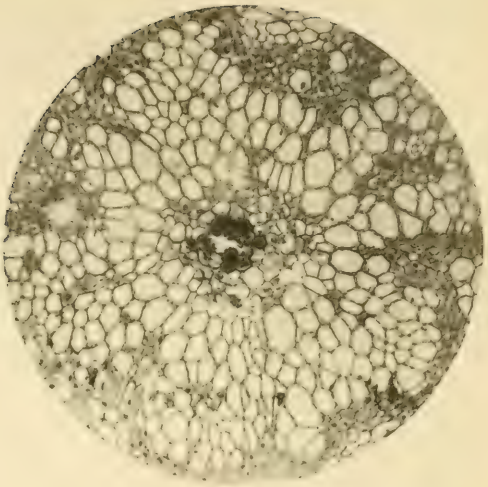

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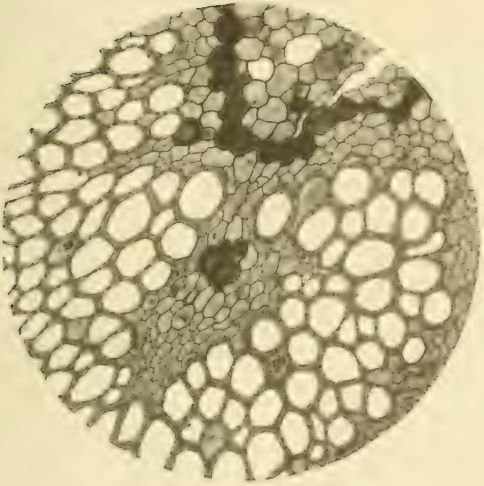

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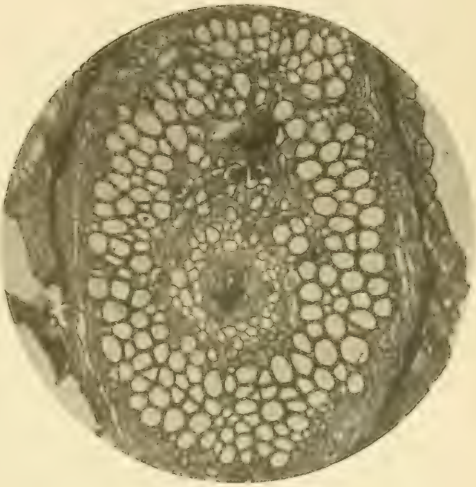

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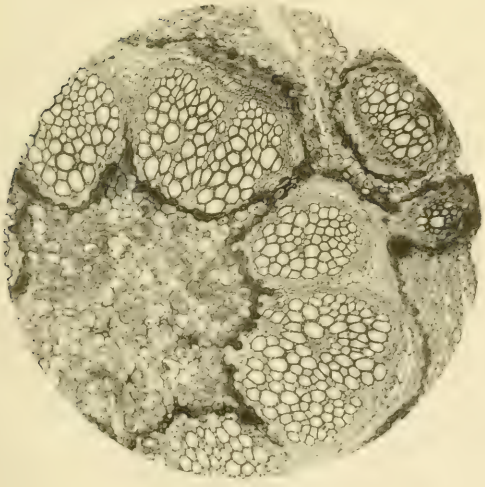

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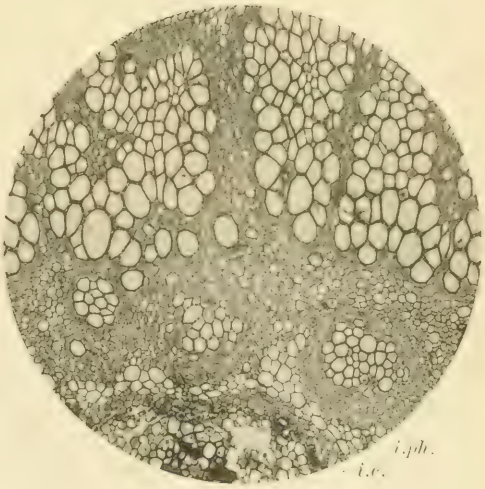

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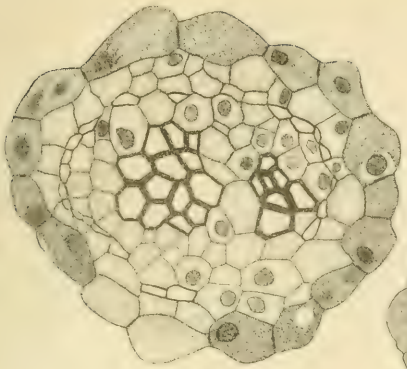

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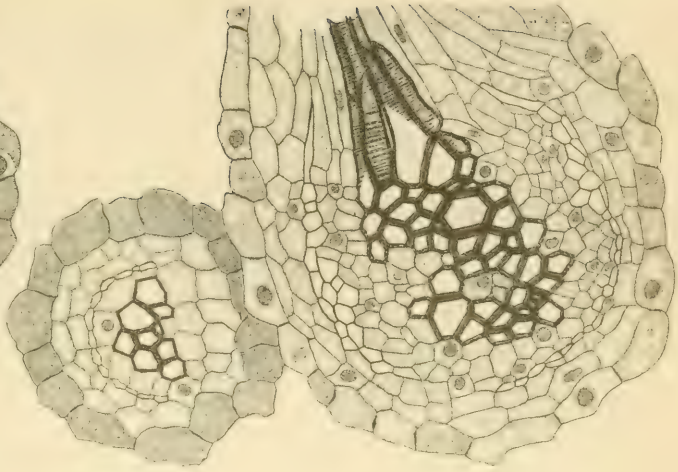

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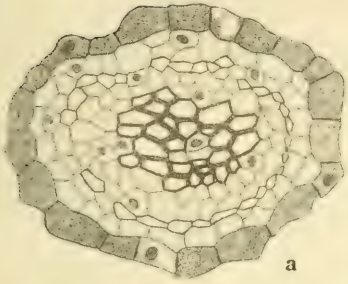

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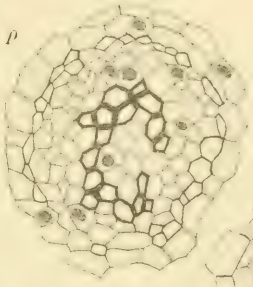

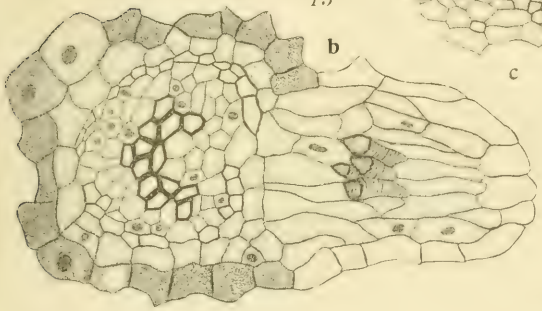

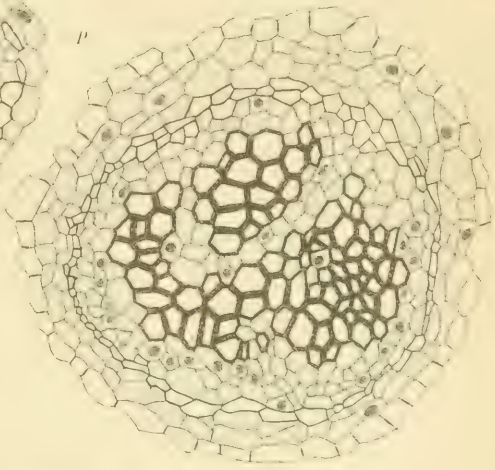

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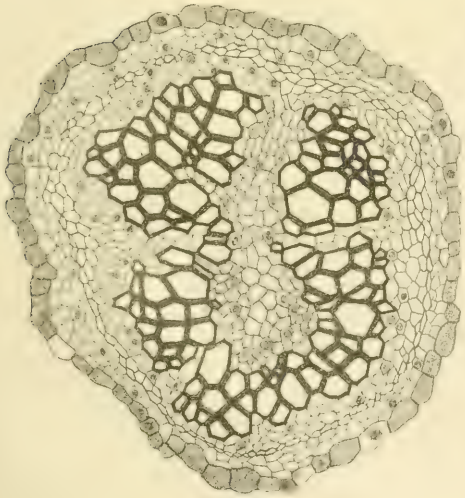

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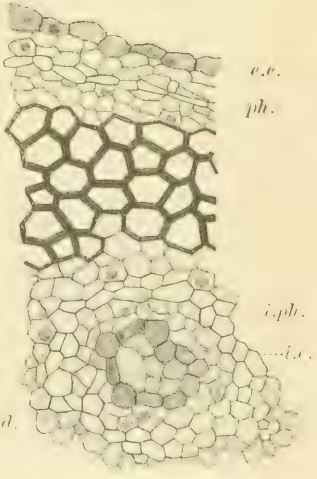

19

PRESIDENTIAL ADDRESS.

HUMAN EVOLUTION AND HUMAN DISEASE.

By Professor J. J. Mackenzie.

(*Read 14th November*, 1908.)

In choosing a subject for my address this evening it is natural that I should select one from my own particular department of Biological Science, viz., the department of Pathology. Perhaps it is not necessary to apologize for so doing, but I have a feeling that among scientific men generally, and I am afraid also among some Pathologists, there has been a tendency to forget that problems of disease, whether in men or in the lower animals, are simply problems in Biology. It is certainly true that Pathology has gained enormously in the past few years from the tendency to view disease phenomena from the broader biological standpoint, in contrast to the older methods of viewing them from the narrow aspect of human pathological anatomy.

This received its first impetus from the development of our knowledge of bacteria as a result of the researches of Pasteur and Koch, but probably the most important step was taken when Metschnikoff in the year, 1884, published his paper in Virchow's Archiv upon the subject of Phagocytosis and, in order to explain the method of destruction of disease germs in the human body, he studied the activities of the amœboid cells in lower forms of animal life. Our knowledge upon this subject has advanced very much since the publication of that paper, but the idea of the activities of phagocytic cells has been a fruitful one in the development of all our views of disease and to Metschnikoff is due the honour of having first recognized the importance of the phenomenon.

But this evening I do not propose to take you into a discussion of any of the many problems connected with this question of phagocytosis, although they are many and intensely interesting. I wish to speak of something about which we have less exact knowledge. To-day, no one thinks of studying the phenomena of human disease without regard to the disease of the rest of the animal kingdom. Indeed, if the view of the older physicians had been held to, that human pathology was something which should be studied apart from animal pathology, we could not have

progressed at all. Comparative Pathology has been the path which has led to the most fruitful acquisition of new and useful knowledge. Disease phenomena, broadly, are the same throughout the whole animal kingdom and, even in their finer details, they are the same among the higher animals. But, while this is true, there are differences which exist between one group and another, and, in regard to individual diseases, we find the most surprising limitations in their distribution. This is true of all disease, but it is especially true of infectious and parasitic diseases and although we find similar organisms producing similar disease in related groups of animals, yet, for many infections and parasites the boundary of the genus or even of the species is often an insurmountable one and we realize, that, with the evolution of a species, there has gone hand in hand with it, the evolution of its diseases. It must not be imagined, of course, that this is a universal law. Many animal diseases may be transmitted to man. Rabies, for instance, infects the human as well as the canine species. The whole mammalian group may be infected by this organism, yet Pasteur showed, in his early work upon Rabies, that the disease picture assumes different forms in different animal groups and especially shows marked variations in its incubation period, as it is passed from one group to another. On the other hand, there are many diseases, of which Leprosy is a good example, which, as far as we know at present, are entirely confined to the human race. In others, as for example, the Trypanosome infections different species infect man from those which infect other animals, in man producing the disease called Sleeping Sickness, in horses and other hoofed animals the various forms of Tsetse Fly Disease, yet the organisms are closely related and the same underlying phenomenon of transmission is present, that is by an intermediate insect host.

These facts present interesting problems in evolution and we cannot examine them without the question pressing upon us: what has been the influence of these diseases upon animal evolution, and how has animal evolution influenced the disease?

The subject which I wish to discuss this evening, is that of the evolution of human disease and its connection with the evolution of the race. In discussing this subject, there are two distinct sides to be considered: first, the evolution of human disease, i.e., the influence upon the cause of disease in man, of the change in the structure and environment of the human race in its evolution from the anthropoid to man, and second, the influence of human disease upon race evolution. The first must of necessity be as yet much a matter of theory, because, in the first place, we can say practically nothing of the diseases of our earliest human an-

cestors and, in the second place, because we know so little of the diseases of our nearest animal relations, the anthropoids. But there is no doubt that many of the purely human infections must have begun fairly low down in the scale of human evolution since we find that the nearer the ape approaches the human form the more certain it is to be infected by purely human parasites. This is seen for instance in the human disease, syphilis, in which Metschnikoff and, more recently, Neisser have shown that the chimpanzee and orang can be infected, developing the disease almost as typically as a man whilst lower monkeys like the macacus only acquire an incomplete infection. There are many other examples such as this, which demonstrate, that if we wish to study human infectious disease in another animal, the most promising results are obtained from a study of the anthropoids. But we must not think from this that these diseases have originated with the anthropoids. This is most unlikely and in many cases, as far as we know, these purely human diseases do not occur among them. It is because of the similarity of tissue structure and blood conditions that the human parasite finds conditions favourable for development, when introduced into the higher apes. In no cases do these animals acquire these purely human diseases with the same certainty as the lowest human individual would acquire them. Infection when it occurs is an artificial condition, not one obtaining in nature. I think we must admit, therefore, that the human diseases we are considering must have originated when the race became more or less like the race of the present time, whether at the stage of Dubois' Pithecanthropos or in the later stages of the cave man, and it seems probable that there were, with the evolution of early man, new conditions set up which favoured the evolution of purely human disease. Let us consider for a moment what these conditions probably were. The best known anthropoids are more or less solitary animals. The gorilla, according to von Koppenfels and other writers, lives in single family groups, consisting of the male and female and their offspring of various ages. Apparently as soon as the young males reach maturity a struggle arises between them and the old male and to the victor belong the females of the group; the vanquished being either killed or driven out. The chimpanzee apparently lives in small families or family groups. The orang also seems to live in small families, consisting of male and female and half-grown young. According to some writers, the adult male orangs live alone, except during the pairing season. In all these animals there seems to be a considerable separation of the family groups and the separation is maintained largely on account of the sexual jealousy of the males.

There is among these wild progenitors of man an isolation of individual groups which prevented the transmission of epidemic diseases. This

condition is more or less true of all wild animals, but not universally so, as we sometimes hear of epidemics sweeping through whole areas, materially reducing the number of given species found in a district, such for instance as the epidemics which periodically sweep off thousands of rabbits in the northwest. But, even with these exceptions, conditions are not favourable among wild forms for the transmission of epidemics, With the evolution of the earliest human forms there was probably more or less breaking down of this isolation between families. The earliest human families must have been compelled, for the sake of mutual protection, to associate more or less closely with one another and out of the family group developed the tribal group with its closer tribal life and the resulting greater opportunities for the transmission within the tribe of acquired infections and parasites. But the change in domestic habits must have played an enormous part in favouring the spread of parasitic diseases. The anthropoids are all arboreal forms. Their life is spent almost entirely in the trees and, in the forests, they move about over a wide area, living continuously in the open air. Apparently several of these higher apes build some sort of nest or sleeping shelter in the trees, but all writers agree, that these are quite temporary structures and are never used for many days in succession. They are of slight importance for the transmission of parasites. How important this nest life is for the passage of disease from one animal to another is seen in the birds where the nests become infected with parasitic insects which apparently serve for the transmission from the parents to the nestling of the blood diseases which are so common among birds. Some time, however, the anthropoid forsook the trees and took to living on the surface of the ground. One writer suggests, that this important step in human evolution was forced upon the anthropoid population by an enormous forest fire, which denuded thousands of square miles of country of the forest growth which sheltered them. This does not perhaps seem likely since forest fires do not occur in the tropical regions where the anthropoids live and where man most probably had his origin, but are peculiar to temperate zones. However, when the parent form took to living on the ground they were naturally driven to cave dwellings for shelter. This becomes more marked the more they migrated to temperate climates and required the shelter during the inclement seasons of the year. But it probably was forced upon the race by the onset of a glacial period. Caves, however, are not common and the cave man, when he secured one, retained it against all comers; it became his castle and was the home of himself, his family and descendants, until it became too small to accommodate them. Here then we have developed a close and intimate association which favoured the spread of infections, once acquired.

Change of food is probably another condition which materially affected the developing human race's tendency to disease. When and how this change took place we cannot say; our present day anthropoids in their natural state feed almost entirely upon fruit and nuts, but all observers say that in their wild condition they may devour young birds and possibly other animal life, if they obtain it. In captivity they readily take to a carnivorous diet. The change probably took place more or less suddenly and certainly all our earliest human records show primitive man to be definitely carnivorous or omnivorous in his habits. Whenever it became general it must have greatly altered human metabolism and it probably actually led to the introduction of certain diseases; it would also alter the normal resistance of the body to introduced or existing diseases.

The definite adoption of the upright habit must also have had an exceedingly important influence on human disease. The step from the quadrupedal to the bipedal carriage was such a tremendous change for the human animal that all sorts of consequences flowed from it, as Metschnikoff calls them dysharmonies, which influence even at the present time our health and our development.

But most important of all was a fact which was first pointed out by Darwin, and which recently von Hansemann has discussed in a most interesting manner at the Lisbon International Congress of Medicine, that is the fact that the greatest step in human evolution was the ability of the human race to rise superior to the ordinary laws of natural selection. Among wild animals natural selection rigidly separated the weak and physically unfit, but in even the earliest human community there was a protection against certain of these selective influences. Its power was slight at first but it was nevertheless far-reaching.

The first human forms which were wise enough to take to a cave dwelling necessarily escaped the selecting influences of inclement weather which might prove fatal to their more exposed, free living, related forms. But such selection among the wild forms serves to destroy the weaker individuals; it selects the strong. The cave dwelling brought about a certain equality between one physically weak and the physically strong and thus one of the most important influences in the propagation of purely human disease developed. In the human family to-day, in contra-distinction to wild animals, a very striking phenomenon of infective disease is the numerous examples of subacute or chronic types. Many of our most serious infections, even those which are not normally looked upon as chronic, are frequently propagated by the persistence of it in a more or less chronic form in certain individuals. This is very true of tuberculosis.

The tuberculous man lives for a varying period of time, protected and prevented from dying. A tuberculous animal in the wild state either recovers or is destroyed by ordinary selective forces, as soon as it becomes too weak to continue the struggle, and this probably takes place very early. That most fatal form of epidemic human disease, bubonic plague, is now traced to certain endemic areas where it persists in a chronic form. To-day, we have just begun to realize that Typhoid Fever persists in a community largely in individuals chronically harbouring the infection, so called typhoid carriers. Again, in malaria, we know from the researches of Koch and others that the majority of the native population in malarial districts is infected with the malaria organism. In this case, those who could not resist the infection have been killed off. The disease has itself acted as a selective factor and a chronic infection persists, which does not materially affect the individual suffering from it, but renders him a menace to all persons coming into his neighbourhood who do not possess a similar resistance. Thus, the more the human race became domesticated, the more it became a prey to chronic and subacute diseases.

Finally, an undoubted influence in the evolution of human disease was the relationship which developed between man and the rest of the animal kingdom, when he took to domesticating animals. This brought about a close association between the human form and other groups, which could not have existed in pre-human times. It is possible that tuberculosis was introduced into the human race under such circumstances. The domestication of the animals themselves was an influence in the propagation of epidemic disease among them, as Von Hansemann has shown. They also suffer because their human master was able to interfere with the rigid natural selection of the wild state. How many of our human infectious diseases are to be traced to domestic animals it is hard to say. Certainly many of the parasitic worms infected man from this source. Many skin diseases probably had the same origin and in the case of one infectious disease at least, viz., smallpox, we may possibly look for its origin among the domestic animals. It has now been proved beyond a doubt that the so-called cowpox, or vaccinia, is simply a milder form of the same disease as human smallpox. It must be admitted, however, that there is probably as much evidence for the view that cowpox originated among cattle through their association with man as the converse. Brinckerhoff and Tyzzer have shown in the Philippines that in the ordinary monkey, inoculation with smallpox virus develops a variolous infection, which, however, histologically is less like human smallpox than the infection in Anthropoids, which is the true *variola inoculata*, but the wide-spread occurrence of vaccinia-like eruptions among domestic animals at least suggests the possibility of an origin from an animal source.

We have thus in a variety of conditions, which are all associated with the domestication of the human race, the circumstances which probably surrounded the evolution of human disease. If we take as a concrete example the infectious disease, which probably is responsible for the largest number of deaths among civilized man, viz., tuberculosis, we see how at every point domestication has favoured the development and spread of the disease. The bacillus of tuberculosis as a disease producing organism, although its special medium of attack is found in man and his domesticated animals, is found not only infecting mammalia, but also birds and even lower vertebrate groups such as the reptilia and fishes. Its career as a parasitic organism possibly began early in the history of the vertebrata, but with the evolution of this group it has changed its character so that we distinguish to-day at least four varieties of the bacillus of tuberculosis, viz., that of cold-blooded animals, that of birds, the so-called bovine type and finally the human variety. The inter-relationship of these varieties is very obscure and a good deal more bacteriological study will have to be done before we can be very positive of the manner in which they have originated. We know, however, that the bacillus found in the cold-blooded animals is more closely related to the bacillus of avian tuberculosis than to the mammalian varieties. The bovine and human type were at one time considered identical, but they have now been clearly separated as distinct varieties, with distinct variation of virulence towards different members of the mammalian group. The bovine type ought clearly to be considered the more primitive because we find that it is capable of infecting in smaller doses and more certainly a larger number of members of mammalian genera than the human form. The human form seems to have been more specialized by its especial association with the genus homo and, as a result, to have lost some of its virulence for other mammals. We practically know nothing of the extent of the occurrence of tuberculosis among the wild mammalia. Cases have been recorded but the organisms have not been isolated and properly studied. Wild animals in captivity, however, readily develop tuberculosis; this is especially true of the apes and herbivora, but when the organism is isolated in these cases in zoological gardens, it is found to belong either to the human or the bovine type. This probably means, at least as far as the occurrence of the human type is concerned, that the captive animals have been infected from human beings with whom they have come in contact. When the bovine type is discovered we must assume either that they have been infected from their food in captivity, especially from milk, or that they have developed in confinement a mammalian tuberculosis which had infected them before capture. The latter view is not unlikely, but much fuller biological study of such cultures must be made before we can be certain.

Our half-human progenitor very probably in the early stages of evolution suffered to the same extent from tuberculosis as other mammalia, but as soon as he took to the cave dwellings he became exposed to conditions which at once preserved the infected individual and also led to infection of other members of the family or tribe, and a more certain preservation of the infecting organism with a more rapid passage from individual to individual which we know from experimental work must have had its influence on the bacillus. With the increase of knowledge which led to the domestication of the large herbivora and especially with the development of the use of milk as a food, there not only came the influence of the spread of tuberculosis among the domestic animals, but a continual re-infection of man from what we may presume was the parent mammalian bacillus.

But there is another interesting character in human tuberculosis which is explained solely by evolutionary hypotheses.. Man may suffer from tuberculosis of any organ of the body, but the organ which is most frequently affected, and affected to the greatest degree, is the lung. Lung infection occurs in other mammalia and the lung probably is an organ which in itself presents favourable soil for the development of mammalian tuberculosis, just as the liver in birds is the favourite site of avian tuberculosis. But man is peculiar in that one particular portion of the lung, viz., the upper or apical portion, is first affected. A variety of explanations are given of this, but the most plausible is that on account of the structure of the human skeleton and the position of the apex of the lung in the thoracic cavity, these upper portions are less completely ventilated and less richly supplied with blood. They form "*loci minoris resistentiæ*" in which the bacillus may unfold its disease-producing characters with better results. But there is a still more interesting point in regard to the lung. In man alone the first rib shows a greater tendency to develop fixity of position than in any other animal. All the ribs are joined to the breast-bone, or sternum, by cartilages which give the great elasticity to the thorax and allows of the proper movement of the lungs in respiration. In very old people these cartilages are apt to become stiff and calcified with a resulting interference with the freedom of respiratory movement. Freund showed many years ago that in tuberculous people, or in those belonging to families which show a tendency to develop tuberculosis, there is an early stiffening or calcification of the cartilage of the first rib with a resulting interference with the movement of the under-lying lung tissue. This earlier calcification of the first rib is not seen among other mammals not even among anthropoids, and it is probably one of the results of our upright carriage, which has produced altered mechanical conditions about the shoulder joint. We thus have a dysharmony arising

in man which favours the development of apical pulmonary tuberculosis and, as a result, general pulmonary tuberculosis with the increased incidence of infection among the immediate companions of the infected person. Thus in tuberculosis all the factors which I have outlined have played their part in converting a disease of comparatively little importance among wild mammals to one of enormous importance among men with in addition the result upon the bacillus that it has taken on new biological characters which now distinguish it from the form from which it originated.

Tuberculosis is perhaps the best example I can give, but we have another human disease—typhoid fever, due to a parasitic micro-organism, which probably illustrates the manner in which human infectious disease has evolved. The bacillus of typhoid fever is an organism which, when cultivated in a pure state, shows characters which we have been accustomed to regard as specific. These characters are not always constant and we find that the more we study races of typhoid bacilli, isolated from different cases and epidemics, that differences become apparent, some of them slight, some of them marked, and we are forced to conclude that spontaneous variations occur. More than this, however, when we extend our survey to bacteria-producing diseases in other animals, such as the bacillus typhi-murium, a related organism of rats, the hog cholera bacillus, the organism found in epidemics of meat poisoning and several other forms, we see how striking are the resemblances to the human bacillus in all their biological characters but especially, as has been pointed out, in a recent paper by Zopnik in the peculiar symptoms of the diseases they produce in the different animals they infect, the ulceration of the lymphatic apparatus of the intestine, the lesions which are found in the lymphatic glands, spleen and bone marrow, even the curious diminution of leucocytes in the blood stream. All these bacteria are distinct species and man is only infected by the varieties of typhoid bacilli, and the so-called paratyphoid forms, never with bacillus typhi murium or hog cholera, but one cannot help thinking that the resemblances point to a common origin and when we pursue the enquiry still farther we find that the nearest form which is not ordinarily disease-producing is the bacillus coli communis, which inhabits the intestine. It is possible that epidemics of a typhoid-like disease existed among mammalia prior to man's advent, but human domestication early gave rise to conditions which would favour the evolution of these diseases. The sanitary conditions of the cave man must have been pretty favourable for the contamination of food and water with filth, and conditions for the rapid spread of enteric diseases would be everywhere present. We do not need even to assume that our present day typhoid is to be traced to a prehuman disease. There are to-day, and have been to a much more marked degree among uncivilized man, conditions which

could lead to the evolution of such a disease after man took to dwelling in caves.

One could multiply similar instances, but probably these two will suffice to illustrate the influences which must have led to the evolution of human disease.

The effect of human disease upon human evolution has been equally important. It has been pointed out that one of the results of the evolution of man, was, that he rose superior to the ordinary workings of the law of natural selection. This, however, is not altogether true, especially of primeval man. Among his progenitors the struggle for existence meant chiefly the struggle for food, and the struggle against the disabilities of his environment, but with the greater incidence of disease, and especially infectious disease, in the human race, disease itself became a selective factor.

In regard to parasitic diseases we may distinguish several types—1st, the type in which recovery means that the body is fortified against a second attack, viz., a definite immunity exists after one attack. Such diseases, for instance, as the eruptive fevers like smallpox, scarlet fever and measles, illustrate this. Exposure of a large human community to such diseases means, first, the weakest are killed off; second, those which survive may be permanently weakened and probably rapidly cease to leave descendants; third, recovery is complete and individual immunity is acquired; fourth, a certain number show a natural immunity and do not contract the disease and probably leave descendants who, more or less, inherit this immunity. Thus with each recurring epidemic there may be established by the selective influence of the disease a resisting population. This type of natural selection is probably responsible for a good many of the phenomena which we witness to-day among the civilized and uncivilized races. Measles is not the serious disease for the civilized races of mankind in Europe and America, where they have been exposed to it for centuries, as it is for the aboriginal races of the Pacific where it has been recently introduced; perhaps we should say re-introduced because probably the progenitors of these races in the Asiatic Continent suffered with the rest of mankind from the various human epidemics in the infancy of the race, but they became naturally isolated and excluded from the selective influences. The same is true of a number of other diseases.

In another type of infectious disease, the spread in the body is slow and chronic; the results are always fatal; no immunity is established. An example of this is Leprosy. Its effect, if given free scope, is to grad-

ually permeate and destroy the race, but here again it is a factor in natural selection and where leprosy existed in continental areas such as Europe, the naturally immune survived and the disappearance from the Continent of Europe of this disease must have been as much due to surviving natural immunity as to the somewhat incomplete sanitary measures of the centuries which preceded the nineteenth.

The recent spread of Sleeping Sickness from West Africa into Uganda, with the result that tribes living about Lake Victoria, have been practically wiped out, illustrates the ruthless way in which disease selection sometimes works. In this instance there is so far as we know at present no recovery and no immunity is therefore established, but the selective influence leads to the destruction of tribes living in the area in which the Glossina fly is found, whilst having no effect upon tribes dwelling in healthier surroundings.

A most interesting suggestion has been made by Dr. Archdale Reid in his studies upon heredity in regard to the effect of alcohol upon the human race. In alcohol we have an example of a poison the discovery of which is comparatively recent in human evolution. One of its most striking effects is upon aboriginal races who have been brought in contact with it by white men. These races succumb rapidly to it and the race deteriorates and dies out. Yet we know that there are nations where alcohol, in the form of light wines, is used continuously and freely without any evidence of racial deterioration. Reid's position is that the longer a race has been in contact with alcohol, the more thoroughly is drunkenness eliminated, since those who develop alcoholism die out and leave fewer descendants, while those who are temperate persist. The ultimate result is the selection of a race who have come to use the less intoxicating alcoholic drinks in moderation. The Mediterranean Europeans are, according to him, examples of the ultimate results of selection; the northern races, of the intermediate stage and aboriginal races of the first stage. A natural objection to raise to this view is that Mohammedans have refrained from the use of alcohol on religious grounds, yet there is no evidence that they show greater susceptibility to its effects and especially to the development of alcoholics than less temperate people. There are other objections, but it must be admitted on a priori grounds that an unlimited exposure of a race to the use of alcohol would in the course of generations eliminate the intemperate. It would, however, take a very long time, and again, we find among the nations the characteristic attitude of the human race towards all natural selective influences and by education and legislation an attempt is made to hurry the evolution. Whether we will be successful remains to be seen.

There is another class of disease in which the influence makes entirely for racial deterioration. This class is illustrated well by malaria. In malaria we have an infectious disease to which man develops a tolerance, but no true immunity. As mentioned above, Koch was the first to show that the native populations in malarial districts are all infected with the malarial parasite, and this observation has been fully confirmed by other students of tropical disease. It is extremely likely that what has been described as an immunity in whites is merely a chronic infection with tolerance. In malarial regions in the tropics the infection is communicated to the children as soon as they are born and it may persist throughout life. Recently an exceedingly interesting study of malaria and its effects upon the nations about the Mediterranean has been published by W. H. S. Jones, of the Perse School, Cambridge. In this he seeks to show that the decadence of Greece between 500—300 B.C., was due to the spread of malaria especially in Attica. Similarly he seeks to show that the Roman decadence at the beginning of the Christian Era was, in part at least, due to the spread of malaria. I have not time to go into the arguments which he uses, but at least he has succeeded in convincing such an eminent authority on malaria as Major Ross. And to-day we certainly know that a malaria infected district is one in which the people show low vitality with a mental dullness which is entirely the results of the poisons of the disease. It may be that the absence of diseases of the type of malaria is accountable for the higher civilizations, which have developed in the temperate zones. Malaria is perhaps only one of the disease factors which lead to the low evolutionary position of the African races. They are also infested with numerous other parasites which lower their vitality. It is an interesting fact that the finest type of the African races have, like the Zulu, developed in the more temperate zones or, like the Masai, in the highlands.

In his prefatory note to Mr. Jones' work, Ronald Ross refers to the apathy and feebleness of the inhabitants of many Indian villages, which has often been observed and he suggests that it is due to the presence of parasitic worms, especially the blood-sucking Anchylostoma, which produces a very chronic type of anæmia. This reference is interesting because the presence of this worm has been demonstrated over large areas of the Southern States and there seems no doubt that the laziness and apathy of the poor white of the south is due to the wide-spread existence of the anæmia of anchylostomiasis. Here we have a factor, which has been of the very greatest influence in retarding the development of a most important section of the Southern United States.

I think I have made it clear that disease, and especially parasitic

disease, has been a most influential factor in human evolution. The human race in the step which it took from the arboreal anthropoid to man, rose above many of the selective influences which up to that point had determined the survival of the fittest, but with that step in evolution a new series of selective influences arose and by no means the least important was disease. With the growth of civilization, however, there grew the knowledge of prophylaxis and step by step we began to interfere again in natural selection and to prevent the selective action of human disease. There are those who say that this is a mistake, that we are thus tending to preserve the unfit. But a very little consideration must show us that this cannot be so, it only seems to be the case because as yet our efforts are not successful but, with improved knowledge and better methods, we must necessarily again rise superior to the slower workings of natural selection and the ultimate result upon the race must be beneficial. It is possible even now to give examples of this successful interference, but perhaps the most striking example of the present day is the fight against malaria and yellow fever in the tropics. How far reaching for tropical civilization this fight will be no one can prophesy, but there can be no doubt that whereas at present there are many tropical regions into which the civilized white man dares not enter, in the years to come he will live in them almost as safely as in the more temperate zones.

And in the temperate zones the fight against all our epidemics, such as tuberculosis, typhoid and other infections must result in a higher evolution of man which will come the more quickly the results of the scientific study of Medicine are applied to disease prophylaxis. It is, and will be delayed by ignorance and prejudice, but here again natural selection will assert itself aud ignorance and prejudice cannot survive.

JAMES BAIN, D.C.L.

The death of Dr. Bain in the prime of his useful life was a sore affliction to his many friends and a severe blow to the Canadian Institute with which he had been connected for many years, having faithfully, in successive years, discharged the duties of Member of Council, Secretary, Treasurer, and President. From infancy he lived in the atmosphere of books (for his father was a bookseller), and his subsequent experience as a publisher eminently qualified him for the office of Librarian to the Toronto Public Library, the development of which was the passion of the last twenty-five years of his life. With pride he watched the erection of the splendid building in which the Library is now housed, but he was not permitted to see its completion. The end came on 22nd May, 1908.

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